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ABSTRACT

This appendix includes seven papers which focus on various aspects of the learning processes of children ages 5-7: (1) S. Thompson, "Transitions to concrete operations: A survey of Piaget's writings" (in outline form); (2) S. H. White, "Changes in learning processes in the late preschool years," an examination of cross-cultural evidence of significant physiological and behavioral changes in children; (3) C. M. Super, "Cognitive changes during the late preschool years: Non-Western evidence for universality," a study in which 13 "culture free" developmentally sensitive tasks were administered to urban and rural Zambian children; (4) C. E. Gunnoe, "The correlation between some measures of neurological and cognitive development in the child"; (5) S. W. White and R. S. Mansfield, "Effects of visual noise on problem solving estimated by an ascending method of limits"; a study which made use of an evolving two-choice discrimination task; (6) R. S. Mansfield, "Developmental trends in the effects of noise on problem solving"; and (7) M. F. Elias, "Three indicators of children's development ability to recognize and solve complex problems," a study which related the ability to hold a labile state to cognitive activity and age. (ED)

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FINAL REPORT

Contract OE 5-10-239

Attentional Processes in Children's Learning:
Appendix A: Project Papers

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Individual Differences

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The research reported herein was performed pursuant to a contract with the Office of Education, U.S. Department of Health, Education, and Welfare. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official Office of Education position or policy.

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3. White, S.H. Some general outlines of the matrix of developmental changes between five and seven years. *Bulletin of the Orton Society*, 1970, 20, 41-57.

4. Super, C.M. Cognitive changes during the late preschool years: Non-Western evidence for universality. Project report to University of Zambia, 1971.

5. Gunnoe, C.E. The correlation between some measures of neurological and cognitive development in the child. Qualifying paper, Harvard Graduate School of Education, 1970.

6. White, S.H., and Mansfield, R.S. Effects of visual noise on problem-solving estimated by an ascending method of limits. Unpublished paper, Harvard University, 1969.

7. Mansfield, R.S. Developmental trends in the effects of noise on problem solving. Unpublished doctoral dissertation, Harvard Graduate School of Education, 1970.

8. Elias, M.F., and White, S.H. Some psychophysiological and latency correlates of rule induction. *Psychonomic Science*, 1969, 16, 84-85.

9. Elias, M.F. Heart rate, skin potential response, and latency of overt response, as indicators of problem recognition and solution. *Psychonomic Science*, 1970, 18, 337-339.

10. Elias, M.F. Three indicators of children's developing ability to recognize and solve complex problems. Unpublished doctoral dissertation, Harvard Graduate School of Education, 1971.

Transitions to Concrete Operations: A Survey of Piaget's Writings

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[1] This study was performed pursuant to Contract OE 5-10-239 with the Cooperative Research Program of the United States Office of Education, under a project of the Harvard University Center for Research and Development on Educational Differences.

Note: The following materials were prepared by Sanford Thompson from a survey of Piaget's writings. Mr. Thompson undertook that survey in 1966-1967, participating through the Faculty Aide program of Harvard College in the project cited above.

A considerable amount of evidence has accumulated from diverse sources to support Piaget's contention that a significant change in children's intellectual processes occurs around age 7 (cf. Kendler and Kendler, 1962; Reese, 1962; White, 1965, 1966a, 1966b). The number and variety of the observed changes are impressive, and it seems important that they be considered all together to see if some better understanding of cause and effect can be inferred from them. Piaget's body of writings is large, and references to behavior change in the age period from 5-7 are scattered through those writings. The survey was undertaken to extract a fairly complete list of the behavior changes noted by Piaget.

There are three main sections in the material that follows:

I. The Transition to Concrete Operations: General Outline. This single-page outline attempts to diagram Piaget's conception of the external forces and internal changes which are important to the development of concrete operations.

II. Explanation of Outline. This section gives a longer account of each entry in the general outline and cites relevant text sources.

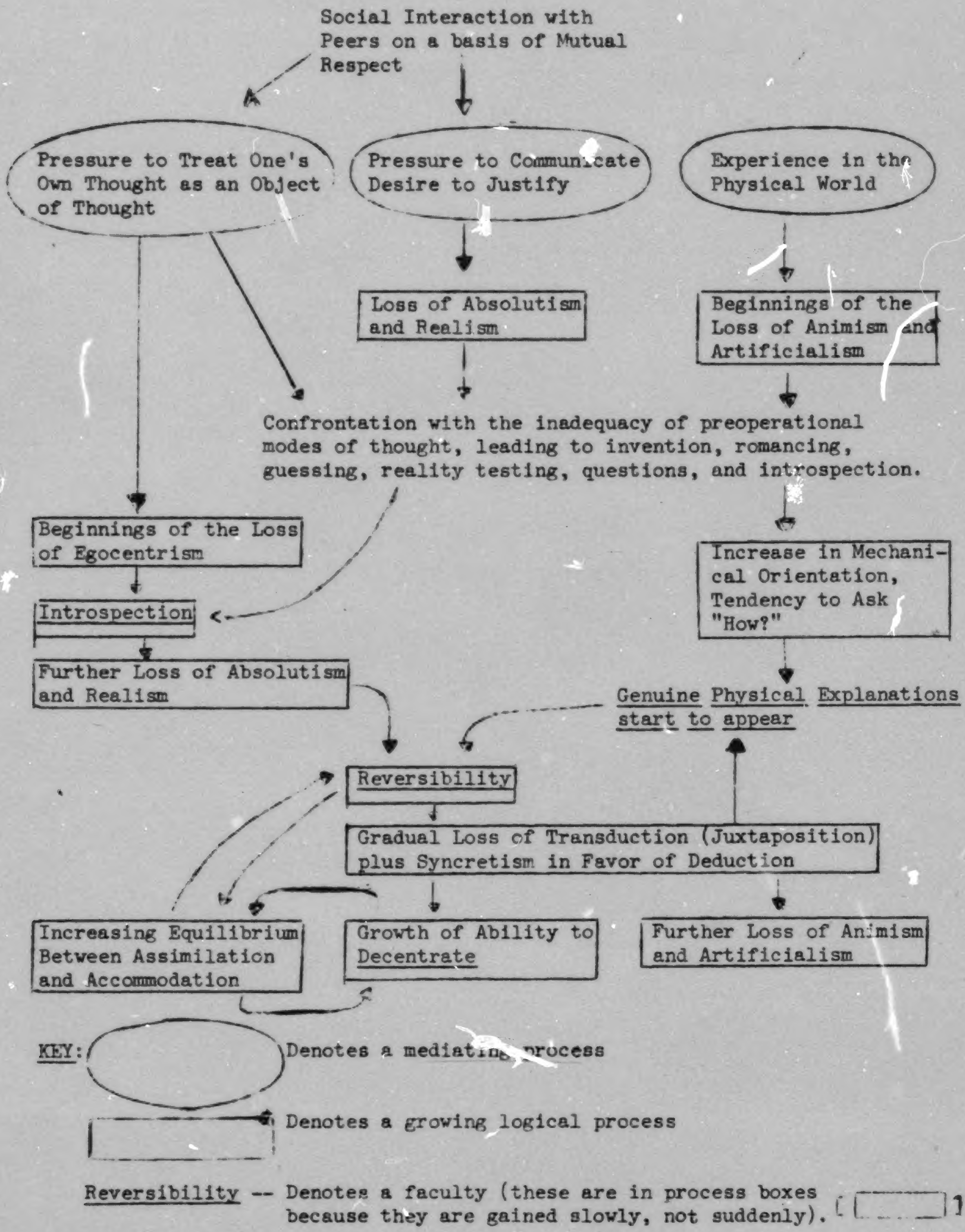
III. List of Behavior Changes Reported by Piaget in the 5-7 Period. This section lists observable indications of intellectual change concomitant with concrete operations. There is a separate outline section for each book. Parenthesized numbers refer to text pages.

The page numbers under Sections II and III refer to the specific editions of Piaget's works which were used in the survey. Those editions are cited in a final Reference section.

Sheldon H. White
July 6, 1967

I. The Transition to Concrete Operations: A General Outline

The processes described in the chart start between 5 and 7, and some come to completion in that time, others to partial completion, but the whole thing is not complete until 11-12.


Social Interaction with Peers on a basis of Mutual Respect
Pressure to Treat One's Own Thought as an Object of Thought
Pressure to Communicate Desire to Justify
Experience in the Physical World
Loss of Absolutism and Realism
Beginnings of the Loss of Animism and Artificialism
Confrontation with the inadequacy of preoperational modes of thought, leading to invention, romancing, guessing, reality testing, questions, and introspection.
Beginnings of the Loss of Egocentrism
Introspection
Further Loss of Absolutism and Realism
Increase in Mechanical Orientation, Tendency to Ask "How?"
Genuine Physical Explanations start to appear
Reversibility
Gradual Loss of Transduction (Juxtaposition) plus Syncretism in Favor of Deduction
Increasing Equilibrium Between Assimilation and Accommodation
Growth of Ability to Decentrate
Further Loss of Animism and Artificialism
KEY:
Denotes a mediating process
Denotes a growing logical process
Reversibility -- Denotes a faculty (these are in process boxes because they are gained slowly, not suddenly).

II. Explanation of Outline

I. Social Interaction with Peers on a Basis of Mutual Respect.

1. Social Interaction (SI) is the primary cause of decrease in monologue and collective monologue around age 7. (Language and Thought of the Child,[1] p. 40-43).

2. Logical thought is reached through the desire to verify, which has social origins. (Judgment and Reasoning in the Child,[2] p. 201-4). "Insofar as he is thinking only for himself, the child has no need to be aware of the mechanism of his reasoning." (JR 213).

3. "Difficulty with terms of discordance are bound up with logical difficulties traceable to social factors." (JR 55).

4. Disillusionment re. parental omniscience sets the stage for the loss of animism, and is contemporary and probably interdependent of increased peer activity. (The Child's Conception of the World,[3] p. 385).

N.B. 5. "...social life is necessary to rational development, but...it is not sufficient to create the power of reasoning... Once it has liberated the appearance of the logical nouns in the child, the social environment enables him to become 'permeable' to experience. And when this faculty has been acquired, the collaboration of logical reason and experience itself suffices to account for the intellectual development that takes place." (The Child's Conception of Physical Causality," p. 252-3). "...as the child discovers that others do not think as he does, he makes efforts to adapt himself to them, he bows to the exigencies of control and verification which are implied by discussion and argument, and thus comes to replace egocentric logic by the true logic created by social life." (PC, 302).

6. The age of 7-8 marks the appearance of the felt need for understanding and cooperation in play. (The Moral Judgment of the Child,[5] p. 27, 43).

7. "...the sense of justice...is largely independent of these (adult) influences, and requires nothing more for its development than

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[1] Abbreviated LT

[2] Abbreviated JR

[3] Abbreviated CW

[4] Abbreviated PC

[5] Abbreviated MJ

(N.B.) Statements so marked provide important links between the social-interaction-as primary-cause model and the inherent-need-for-logical-equilibrium-as-primary-cause model. (Both these models, of course, posit physical experience as a necessary mediator.)

the mutual respect and solidarity which holds among children themselves. It is often at the expense of the adult (alternate translation; in spite of the adult?) and not because of him that the notions of just and unjust find their way into the youthful mind." (MJ, p. 198).

8. Finalism and the omnipotence of man are a projection of the child-parent relationship. (CW, p. 371).

II. Pressure to Communicate: Desire to Justify.

1. "What is socialized in language belongs only to the factual categories of thought...From this age (7-8) onwards they try to improve on their methods of interchanging ideas..." (LT, p. 49).

2. Conversation, both in the form of collaboration and the form of argument, goes through several stages, involving more and more explicit, precise, and abstract speech. (LT, 56-72).

3. Verbal expression can transform a general schema of experience into a general law. But verbal expression depends on the desire to communicate and convince. (JR, p. 30).

4. Logical thought is reached through the desire to justify, which has social origins. (JR, p. 201-4).

5. 7-8 marks the appearance of a felt need for cooperation in games. (MJ, p. 42).

6. What pushes logical development is the felt need to go beyond the self, consider and integrate other points of view, and represent reality to the self independent of present actions. The child is only motivated to do this in order to be able to communicate. (The Construction of Reality in the Child,[1] p. 366-7).

III. Pressure to Treat one's own thought as an object of Thought.

1. Before the age of 7-8, the explainer and the listener both think that all the information has gotten across, though this is, of course, not true, and can be socially maladaptive. Explanations are sketchy and touch factual categories only, not logical or causal relations. (LT, p. 100-107, 119-121).

2. Collaboration and conflict begin to become verbal around 6, become complex and use logic and causality around 7 1/2, which naturally implies that the child can think about his and his peer's thought. (LT, p. 58-72).

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[1] Abbreviated CRC

3. Children below 11 or so cannot assume "for the sake of argument" a point of view in which they disbelieve. (JR 64-69).

4. The ability to take another point of view means you have a much harder time distorting data through over-assimilation or accommodation you are able to regulate your own thought. (JR, p. 173-180).

5. Between 7 and 11, treatment of thought as an object of thought is still imperfect. To be able to express a general action schema, the child must conceptualize it, recreate the action in his imagination (constantly checking the mental experiment with his memory of the physical one!) and stay conscious of what he is doing. This process calls forth, on the verbal plane, all the difficulties that had previously been overcome on the plane of action. Thus the child's verbal behavior displays transduction, nonconservation of substance, inability to decentrate or consider more than one variable at once, etc., long after his actions have ceased doing so. It is continued social interaction which keeps him trying, so that eventually the "shifting" (décalage) is also overcome, around the age of 11-12. (JR, p. 213-215).

6. Becoming aware of a category of thought changes the nature of that category. (LT, p. 229). "Egocentric habits of thought have a considerable effect upon the structure of thought itself." (JR, p. 1).

7. As the child slowly learns to distinguish the world from himself (examples of indissociation in this respect include animism; endowing things with motive and purpose because motive and purpose so pervade the child's life that he "naturally" assumes them to be universal), adherences of the two realms of experiences still remain -- "fragments of internal experiences which still cling to the external world." These adherences include participation, animism, artificialism, finalism, and the generalized idea of force. These adherences disappear through a growing process of self-awareness --

    a. Becoming aware of "the existence and the mechanism" of one's own thought (examples; separation of signifiers from things signified; concept of thought as inside the head and the end of its participation with speaking, the voice, and wind).

    b. Discovery of the inwardness of thought weakens and destroys animism, strengthens a mechanical view of the world.

    c. Becoming "conscious of subjectivity" causes one to become rid of egocentricity, which also diminishes finalism and artificialism. (PC, p. 244-246).

8. With increased social intercourse appear two important developments --

a. Interpretation properly so called -- not in accord with egocentric pre-relations, but in accord with other possible points of view, of which the child's own is only one.

b. Logical realism begins to disappear, and the notion of reciprocal relations is established. The child can see that he is a brother to his brother, that left and right depend on which way one is facing, etc. (PC, p. 247-248).

9. From 2-7, the child has great ease at imitating and making internal images. It is not until 7-8 that he becomes fully aware of what he is doing and is able to do it deliberately and integrate it into consciousness as a whole. (Play, Dreams, and Imitation in Childhood,[1] p. 72-73).

Imitation undergoes a threefold progress around 7-8;

a. There is attention to detail-analysis.

b. There is consciousness of imitation-dissociation of the ego from the outside world, and

c. There is discrimination-use of imitation for particular purposes, and those purposes are well understood and identified. (PDI, p. 78).

IV. Experience in the Physical World.

1. The child has no conception of chance (LT, p. 147) (PC, p. 277) which is an index of the loss of moral realism as applied to physical events, but also of increasing familiarity with the environment.

2. There is an increase of "how" questions, and of explanations involving physical cause rather than precausality. (LT, p. 221-225).

3. The child of 7 begins to look for efficient rather than artificialist causes of natural phenomena. (CW, p. 288-9, 295-6, 301-5). This is the stage of technical (as opposed to mythological) artificialism (CW, p. 373-4).

4. Around 7, the child begins to take a spontaneous interest in machines and mechanical explanations. He abandons the vague idea that the parts of a bicycle are all necessary, but all unrelated (juxtaposition) for a search for contacts and an irreversible transmission of force, which quickly develops into the correct explanation. (PC, p. 210-212).

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[1] Abbreviated PDI

5. "Once it has liberated the appearance of the logical nouns in the child, the social environment enables him to become 'permeable' to experience. And when this faculty has been acquired, the collaboration of logical reason and experience itself suffices to account for the intellectual development that takes place." (PC, p. 252-3).

6. Physical experience is what provides the standards for a child's mental experiments, starting around 7 and reaching logical coherence around 11. (JR, p. 213-215).

   Note -- Piaget does not accord physical experience a very important causal position in his scheme of causality. It is obviously necessary to life and thought, but I think Piaget thinks that physical experience must be looked at in the proper way before it can yield schemas, concepts, and contributions to logical growth. And the original point of view or way of looking at experience must originate from something other than experience.

7. The child understands nature better once he has understood machines. (PC, p. 231-3).

8. Around 7-8, a child systematically explores, with his hands, an object that he can't see. True conception of space is based upon activity, not mere perception. (Child's Conception of Space.[1] p. 22-29, 37-40).

V. Beginnings of the Loss of Animism and Artificialism.

1. Animism is restricted to things that move (leaves, clouds, rivers -- not stones or houses, which were animate previous to 6 1/2-7). (CW, p. 179-182). This stage is transitional to the third stage -- only things that move of their own accord (excl. bicycles, machines, etc.) (CW, p. 181), reached about 8 1/2.

2. "Conscious" and "Alive" are not synonyms. Forty percent of the children were at the same stage regarding both. Forty percent were more advanced regarding life, and twenty percent were more advanced regarding consciousness -- so consciousness seems to have a wider extension. (CW, p. 204-5).

3. Animism is caused by:

   a. Finalism (product of egocentrism)

   b. Connection of "cause" with "purpose," and

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[1] Abbreviated CCS

  c. Confusion of physical and moral necessity (both are products of over assimilation of outside world to existing schemas, known as indissociation, and attributing subjective feelings to objects; introjection.) (CW, p. 231-242).

4. Artificialism is a product of finalism, which is a product of egocentrism. Participation is felt between the mountains, or the moon, or anything else, and man; and this is expressed as the human manufacture of something living. (CW, p. 263-272).

5. Around 7, children start to look for an efficient cause -- like smoke as the cause of clouds. (CW, p. 273-280) (Examples: CW, p. 273-350).

6. Indifferentiation causes the child to see purpose and plan everywhere, and he naturally attributes these plans to men. (CW, p. 359).

7. Animism and Artificialism are on the way out when the child begins to ask "how," and to feel the need for a causal agent. (CW, p. 373-4). Causes for the decline of animism and artificialism are:

   a. Disillusionment about parental omnipotence (social),

   b. Decrease of egocentrism, and

   c. Onset of socialization (individual).

8. The appearance of the idea of "reflex" around 7 is perhaps the most primitive technical artificialist concept -- air displaced (or created) by a moving object swirls around behind it and helps push it along. (PC, p. 21-24).

9. The notion of a true causality is partly dependent on the establishment of the reversible series -- processes can also be undone. Since mental processes are irreversible, desubjectification must occur before this can really start to change. (PC, p. 271).

10. "Causality is the result of a sort of bodily contact between the organism and the world, which is prior to consciousness of self..." (PC, p. 272). This leads, around 7, to a generally physical conception of causality, though the idea of logical necessity is not yet present. (PC, p. 277-281).

VI. Loss of Absolutism and Realism.

1. The child moves away from syncretism in his perceptive intelligence around 7, though verbal syncretism remains until 12 or so. (LT, p. 128).

2. The child moves away from adherences insofar as he becomes aware of his subjectivity, moving in the threefold process from realism to objectivity, to reciprocity, and to relativity (social-intellectual, social, and intellectual) (see heading III, numbers 6 and 7 (p. 3)) (PC, p. 246-251).

3. The child can come to understand the nature and existence of general laws through expression of them; he already has, of course, a corresponding action schema, but verbal expression brings it to consciousness, and gives it a feeling of logical necessity, thus moving the child away from exclusive awareness of cases and realism. (JR, p. 29-30).

4. After 7-8, a child is able to take a hypothetical viewpoint, to distinguish hypothesis from reality. (JR, p. 67).

5. From 7 onwards, children are able to think of themselves as their brothers' brother (no difference between only children and siblings in this respect). (JR, p. 106). Around 8 or so, children are able to judge right and left from the viewpoint of another person, facing them. (JR, p. 107). Before this, however, "brother" and "left" are absolute categories, and does not perceive the implied relation. A family is identified, not by kinship, but because they all live together in a house. (JR, p. 115-19).

6. The child of 6 thinks thought is with the mouth; thought is identified with the voice. Around 7, it remains a voice, but inside the head. (CW, p. 39-52).

7. Until 7, the child identifies a name with its referent. From 7 to 11, the identification persists, though the child perceives that the word and the thing aren't the same. (CW, p. 55-60).

8. Concerning the origin of names, children until 7 think the name is an intrinsic and unalterable part of the thing. From 7 to 11, the name was made up by the makers — God or first men. (CW, p. 63-70). The name is not localized, though it surrounds the object, it is in the air, everywhere. (CW, p. 75-87).

9. Around 7, the child begins to believe that dreams arise within ourselves but are actually present in the room. (CW, p. 106-117).

10. An example of Décalage -- around 7, children become aware of the rules of the game of marbles, but consider them absolute and sacred -- at just the time they are moving away from absolutism in perceptive intelligence. (MJ, p. 56-65).

11. Moral Realism -- Naughtiness depends on the amount of damage, (MJ, p. 121-130) not the intent. A lie is anything that is not true, mistake or not (MJ, p. 139-146). This is not always the case in practice. A child knows a lie from an error, and he knows how to distinguish motive from deed. But he doesn't do it. (There is a whole section in MJ on this -- p. 109-196). Piaget thinks moral realism comes from the sacred character of adult rules, which *do not* correspond to any felt need on the child's part. The rules are only comprehended through "interiorization"-socialization (MJ, p. 163). Around 7 to around 11, a lie is wrong in itself -- no consideration of the purpose of having such a rule (MJ, p. 169). This realism is thus not entirely spontaneous -- it is partly a product of adult constraint, of the situation of unilateral respect which exists between the child and the adult. (MJ, p. 135) (MJ, p. 194-6).

12. Punishment before 7 is expiatory -- to pay for having broken a rule. From 7 to 11 it is retribute -- to restore balance, often to the point of mathematical exactness. The idea that punishment is valuable as a deterrent and a reinforcer of solidarity does not come until about 11. (MJ, p. 205, 217-18, 227-32). Unilateral respect is present here, too.

13. Immanent Justice -- the notion that inanimate objects conspire to punish the wicked -- decreases with age (7-8, 73% of the sample believe in it. 9-10, 54% do) (MJ, p. 253).

14. 7-8 is the age when equality wins out over authority. Equity becomes dominant about 12-13. (MJ, p. 269, 278).

15. Between 7 and 9, the child renounces the notion of absolute weight in explaining why objects float, and begins relating weight to volume, even bringing the notion of specific gravity (The Growth of Logical Thinking from Childhood to Adolescence,[1] p. 28-35) (PC, p. 136-150).

VII. Confrontation with the Inadequacy of Preoperational Modes of thought leading to invention, romancing, guessing, reality testing, question, and introspection.

1. Clapaiede's law "We only become conscious in proportion to our disadaptation" (JR, p. 213). "A question is the conscious realization of a problem or of the difficulty, i.e., of the direction in which to seek for its solution." (LT, p. 227-8).

2. Around 3, when the child begins to distinguish the imaginary from the real, he also begins to distinguish, and to feel discord between, his desires and the realization of them.

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[1] Abbreviated GLT

(Causality is probably from the latter to the former)... "The child takes cognizance of the resistance set up by things and people..." Since the child can't distinguish animate from inanimate, this discord is perceived as intentional resistance. Furthermore, everything seems to obey some sort of necessity which is both moral and physical.

N.B. 3. Between 6 and 8 the child is no longer satisfied with "explaining away" phenomena in terms of the most plausible variable that comes to mind. He wants to find something that can work in all cases, that is consistent with itself and with the facts. Pure mental experiment (reproduction of the event in the mind) cannot do this -- reality does not impose an interpretation. Rather the child must ask "What if...?" and account for consequences, causes, proofs, relations. "We have here an experiment which thought makes, not on things, but on itself, in order to find out what greater measure of fertility or of logical satisfaction it will gain from such and such a system of definitions or premises." (JR, p. 189-194; quote is on 193-4). "Logical experiment is therefore an experiment carried out on oneself for the detection of contradiction." (JR, p. 237).

4. Considering only one aspect of a perception in order to judge equivalence leads to incorrect answers, which puzzle and baffle the child. Trying out experiments, which eventually lead to the right answer, are partly to gain certainty. (The Child's Conception of Number,[1] p. 87). (Can this be called avoidance learning?)

VIII. Beginnings of the Loss of Egocentrism

1. Monologue (individual and collective) and egocentric speech begins to diminish around 7. (LT, p. 41-2).

2. "...egocentric habits have a considerable effect upon the structure of thought itself." (JR, p. 1).

3. Egocentrism prevents the desire for objective proof. (JR, p. 24).

4. When egocentrism has diminished to the extent that the child can imagine several points of view toward something, assimilation and accommodation have a much harder time distorting one another, and the child is on the way to being able to coordinate different viewpoints. (JR, p. 173-180).

5. In order to cease confusing the subjective and the objective, the mind must become aware of itself. It does this primarily via social contact. (CW, p. 245).

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[1] Abbreviated CCN

6. In the child of 7, who is looking for efficient causes and mechanical explanations, a lot of precausal finalism remains. (Night is to let us sleep. Parents/definition!/are to take care of us.) And finalism is a product of egocentrism, in a very primitive form. (CW, p. 288-90).

7. The growth of thought can be characterized in terms of three processes -- growth from

    a. realism to objectivity;

    b. realism to reciprocity;

    c. realism to relativity. (PC, p. 241-250).

8. As the child interacts with his peers, he adapts himself to the exigencies of control and verification, and so egocentrism is gradually lost (PC, p. 302).

9. Around 7, cooperation in games, based on rules, begins to appear. (MJ, p. 28, 43-47).

10. On moral issues, such as lying or how to gauge responsibility, the child is still realistic. But in social ones, such as the function of punishment, he has moved from realism to a stage of equalitarianism (which he overdoes to the point of vengeance), which is a step away from egocentrism. (MJ, p. 201-17, 315).

IX. Introspection

1. Genuine introspection is found from about 7 or so. (JR, p. 143). It gets more frequent until 12 when it is quite frequent. (JR, p. 143).

2. Consciousness moves in an irreversible stream -- and the young kid can't recapture what went on before. He contradicts himself and forgets the reasons for his previous statements.

    a. by amnesia -- forgetting his previous idea completely, and

    b. by condensation -- hearing two standards or explanations, and forgetting one or both, or fusing them in an unintelligible way. (JR, p. 164-7).

3. Introspection, and the end of confusion between the self and the world, are both necessary for one another and reinforce one another in a mutually nourishing cycle. (CW, p. 245) (PC, p. 251-6).

4. The child gains a sense of causality through three processes

    a. Desubjectification of causality

    b. Creation of temporal series

    c. Progressive establishment of reversible series.

    Each successive loss of confusion and egocentrism increases introspection, and makes possible the next bit of growth. (PC, p. 267-271).

5. The child begins with "no more direct cognizance of the self than ... of external objects ... it is for lack of having discovered his own subjectivity that the young child feels his gestures, his words, and his thoughts, to be bound up with the objects themselves." (PC, p. 272).

6. "Causality is the result of a sort of bodily contact between the organism and the world, which is prior to consciousness of self..." (PC, p. 272).

7. "Corresponding stages are at varying levels, because the influence of one belief upon another takes place unconsciously and not thanks to a conscious and deliberate generalization" (JR, p. 292) i.e., introspection is a product of growth, and not a means until fairly late ... For instance --

8. Representative imitation becomes deliberate and takes its place in intelligence as a whole around the age of 7. (PDI, p. 72). This is partly a result of a growing introspective capacity. It is also, very possibly, a means to still further understanding of the mechanism of thought.

X. Increase in Mechanical Orientation -- Tendency to ask the Question "How?".

1. A genuine idea of chance appears around 7. (LT, p. 145, 205-6).

2. The child at 7 begins to look for efficient causes of natural phenomena. (CW, p. 288-9). This is technical or "mediate" artificialism. (CW, p. 373-4).

3. With the dimunition of confusion between the self and reality, animist or artificialist explanations are felt as insufficient, and the child begins to ask "how"-questions. (PC, p. 267-271).

4. At the age of 8 boys can give an explanation of how a bicycle works, plus a spontaneous drawing. This is preceded by a stage, lasting until about 7, when the child thinks that all

the parts are necessary, but simply juxtaposes them without relating them -- ego, the explanation of the movement is syncretistic. Boys of this age are also very interested in machines. (PC, p. 197, 210). At this age, he is also able to explain a steam engine. (PC, p. 223-5, 231-3).

5. From 7 on, the child makes an effort to understand his physical models through representative imitation. (PDI, p. 76-78).

XI. Reversibility

1. Irreversibility is the result of the continuous assimilative activity of the mind. The child, when he makes a mental action, does not keep all the terms separate. A + B → C, but A and B are partly assimilated by C, and the child is not even aware that this has happened. (JR, p. 167-173).
2. To have reversibility, you must have imitation to keep A and B apart while you are finding C. (JR, p. 177).
3. From 7-8 to 11-12, mental operations tend toward reversibility. (JR, p. 189-192).
4. "...egocentric habits of thought have a considerable effect upon the structure of thought itself." (JR, p. 1).
5. In the development of causality, reversibility is indispensible. Reversible series must be established, the child must be able to see that processes can go in either direction. (PC, p. 270-271).
6. Around 7, the child becomes able to analyze and reconstruct a model through imitation, without distorting it. (PDI, p. 75-78).
7. Cognitive representation can give an overview of several perceptions, and aims at comprehension as such rather than at satisfaction of immediate material aims. In order for this to be possible, a system of mobile, reversible mental operations must be set up. (PDI, p. 238-9).
8. Around 7-8, the child is able to formulate, with increasing accuracy, the relation of reciprocal implication. (GLT, p. 7-8). To explain buoyancy, the kids around 7-8 stop contradicting themselves and start separating variables and keeping them in mind.
9. The conceptual equilibrium of thought is both modile and permanent, which means it is reversible. (Psychology of Intelligence,"[*] p. 48).

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[*] Abbreviated PI

10. Beginning about 6, and reliably about 7, the child can use compensation of dimensions reasoning to conclude that the amounts of liquid in differently shaped containers are the same. This is based upon a conception of reversibility. (CCN, p. 13-23, 29-32).

XII. Gradual Loss of Transduction (Juxtaposition plus syncretism) in favor of Deduction

1. Syncretism is marked by
    a. Nondiscursiveness -- thought goes right from premise to conclusion in a single intuitive act;
    b. Use of schema of imagery rather than concepts;
    c. Use of analogy, rather than comparison;
    d. The presence of belief and conviction, which dispels any need for demonstration. (LT, p. 127).
2. Habits of transduction seem to begin to disappear around 7-8. (LT, p. 128).
3. Syncretism of reasoning -- the proverbs experiment -- assimilation of all perceptible elements of the proverb to a general schema. This is used in finding a "corresponding phrase," and there is mutual assimilation between it and the phrase. (LT, p. 142-3).
4. Syncretism of perception -- a few prominent details form a pattern which is noticed and remembered -- it is because of these details that there is a whole.
5. Children only use logical justification very imperfectly until 7-8. "Then" in a logical sense is used only in the case of particulars -- there is no appeal to an underlying general case. (JR, p. 32-36).
6. Three characteristics of child thought -- absence of conscious realization, absence of general propositions, and absence of deduction -- are all explained by "juxtaposition." (JR, p. 57).
7. Juxtaposition (absence of relations), and syncretism (creation of an all inclusive schema,)supplanting the details, are complementary -- they are both used as substitutes for analyses. (JR, p. 59).
8. Transduction is inference from particular to particular without generalization. It is a combination of elementary relations, but without reciprocity of these relations amongst each other,

and consequently without the element of necessity that leads to generalization. (JR, p. 189, 198).

9. The hard thing is to learn to impose a definition and to reason within its limits. It is tried by the child as an experiment, to see what sort of satisfaction will result. This is "a logical experiment" -- an experiment of thought upon itself. (JR, p. 193-4).

10. From 7-8 to 11-12, mental operations tend toward reversibility, reciprocity, and thus a sense of logical necessity, through the development of rigor and of the ability and disposition to generalize. (JR, p. 18[illegible]188).

11. Participation -- which [illegible] "the ontological equivalent of transduction" (JR, p. 303), begins to vanish around 7-8, as the child evolves from realism to objectivity, that is, comprehension of the fact that an object has no life or will. (JR, p. 243-5).

12. The development of object constancy depends on three other faculties:
    a. Foresight -- ability to foresee the reappearance of bodies;
    b. Coordination of schemata which make it possible to realize that each of these bodies has lots of interconnected qualities;
    c. Deduction, which makes it possible to reconcile the idea of actual permanence with the apparent variations. (CRC, p. 371-2).

13. The decline of transduction is clearly shown by the growth of the idea that something is logically a necessity, rather than an empirical probability. (PI, p. 140).

XIII. Growth of Ability to Decentrate

1. In reasoning about events, the child is aware only of cases, not of general laws. (JR, p. 29, 57).

2. The phenomenon of child animism can be understood as two processes which strengthen each other; indissociation of physical and psychological reality, and introjection of the child's own feelings into the objects to which he is attending. (CW, p. 237-244). These two notions are so persistent because the events to which they refer can't be experimentally proven to happen otherwise. Only a change in thinking habits can lead to the end of indissociation and introjection. (CW, p. 238-9).

3. A child of 8 was not able to explain why water rises in a glass when you put wood or pebbles in. It is because the pebbles are "heavy" or the wood is "big." His explanation is overdetermined, and he cannot separate out variables like size and weight, or relate them to get density. (JR, p. 180-186).

4. The child below 7-8 is the victim of misleading perceptions which cause "incomplete intellectual constructions." (PI, p. 130).

5. The child centers on one aspect of the beaker (of water or beads) at a time -- either height or width, but not both at once. (PI, p. 130-131).

6. Every decentralization, undertaken to correct an error, is a regulation and a move toward reversibility and coordination of viewpoints. (PI, p. 138-9).

XIV. Equilibrium between assimilation and accommodation

1. When the child is able to take another point of view, he is less able to distort the data by conflicting assimilation and accommodation, and blurring of terms. (JR, p. 173-180).

2. As the child reaches 7-8, assimilation and accommodation tend toward reversibility, but achieve it only in the framework of certain special configurations. (PDI, p. 277-281).

3. Example of conflict between assimilation and accommodation -- the child is:

   a. unable to take another point of view than his own, and

   b. very much at the mercy of the opinion of his group in his viewpoint and speech. (CRC, p. 363).

4. Development is governed by an inherent need for equilibrium. At each stage, the mechanism provided by the factors in existence makes for an equilibrium which is still incomplete, and the balancing process itself leads thought to the next level. (PI, p. 47-49).

5. "The crucial turning point for the beginning of operations shows itself in a kind of equilibration which is always rapid and sometimes sudden, which affects the complex of ideas forming a single system." (PI, p. 139).

III. List of Behavior Changes reported by Piaget in 5-7 period

I. Language and Thought of the Child

1. Diminution of collective monologue (18, 56-8).
2. Growth of collaboration on concrete issues - 5-7 (58-63).
3. Collaboration in abstract thought - from 7 on (63-5).
4. (The growth of conflict follows the same stages).
5. The growth of the explanation, which allows for the listener's ignorance and his point of view -- from 7 on (107-120).
6. Habits of transductive reasoning begin to disappear around 7-8 (127-8).
7. The idea of chance appears in the child, thus syncretistic justifications at any price diminish (147-8).
8. The "why" of logical justification, rather than that of psychological motivation, causal and finalistic explanation, of justification of rules (164-6) (Extended discussion 171-199).
9. Decline of precausality (the tendency to justify everything by syncretistic explanations) (220-227).

II. Judgment and Reasoning in the Child

1. Correct management of the relation of implication -- age 7-8 (23).
2. Beginnings of correct management of relation of discordance -- age 7-8 (47).
3. Around 7-8, the child can use deductive logic, if he personally believes in the premises of the argument (67).
4. Around 7-8, the child can handle relational judgments (as on the 3-brothers test), though his old mistakes show up on the verbal plane until 11 (92).
5. This (#4) is an indication of decline in realism and absolutism.
6. Genuine introspection is found from 7 on, though only in spots (143).

7. The child is able to give definitions of a sort around 7 (149).

8. From 7-8 on, mental operations tend toward reversibility-reciprocity of consequence and cause; logical necessity (187).

9. Thus, Transduction begins to decline from 7 on.

10. The logical experiment is found from 7 on.

III. The Child's Conception of the World

1. Thought moves from the mouth to the head, but the child still thinks thought is material (49).

2. The child ceases to regard names as intrinsically connected with their referents, and believes that God or the first man named things, and that the name could have been different (68-9).

3. The child comes to think that dreams arise within him, but take place outside him, in the room (106-117).

4. All these three things belong to the stage of "mediate" realism, where thought and its instruments are in the surrounding air or space as well as in the body (126).

5. The child restricts consciousness to things that move (wind, rivers, bicycles, etc.), rather than attributing it to everything (179-182), lasts until 9 or so.

6. At about the same time, but probably a little earlier (see discussion on 204-5), the child assimilates life to things which move (199-201). There is no distinction made, here or in #4 (consciousness) between spontaneous and imparted movement.

7. 7 is the age when children begin to look for an efficient cause of natural objects (like smoke from chimneys causing clouds) rather than a purely artificialist one (men or God fashioned the clouds directly) (288-9). This set of stages hold true for night (290-8), clouds (298-307, thunder and lightning (307-311), rain (311-320), snow, ice, and cold (320-326), rivers, lakes, and the origin of water (326-333), trees, mountains, and earth (333-349).

8. The sequence of these stages is invariant, but the age at which they are attained varies as much as two years, (7 in Geneva, 9 in Spain) (306).

9. Around 5 1/2-6 finalism and diffuse artificialism begin to disappear, to be replaced by mythological artificialism (which

involves direct creation of things by men), and this gives way, around 7 1/2, to "mediate," or technical artificialism (369-374).

IV. The Child's Conception of Physical Causality

1. About 5 1/3, the child imagines participation of wind with air from the hands, or a bicycle pump, or breaks. Bodies like the sun and moon are considered living. (p. 6-114 — full of examples).
2. Around 7, the child starts looking for a physical explanation for the floating of boats, the level of water, shadows (142-195).
3. The child starts looking for an irreversible order in the operation of machines (211-12, 223-5, 226-236).
4. The child overcomes adherences by three things -- becoming aware of how his thought works, understanding that thought is interior, and the loss of egocentricity (246).
5. The child of 7 begins to differentiate moral and physical necessity from each other (276-80).
6. Discovery of the logic of relations precedes that of classes (298-300).

V. The Moral Judgment of the Child

1. Appearance of cooperation in games with rules, though the rules themselves are not well understood (26-8).
2. Appearance of awareness of rules, going along with a belief that they are sacred and eternal (28).
3. The stage of cooperation is defined by a felt need for understanding (42).
4. Though the child of 5-7 submits completely to the rules in intention they remain external to his conscience in practice.
5. Around 7-8, children begin to switch from objective to subjective conceptions of responsibility -- that intent must be taken into account as well as consequences (124).
6. Of course, the child of 6-7 is perfectly able to judge on the basis of intent, and gives himself breaks this way all the time. And some children give subjective judgments all along.

So Piaget thinks that objective responsibility is a combination of the effect of childish thinking and adult constraint. (128-135).

7. The child of 6 stops thinking of a lie as a naughty word, and begins thinking it is anything untrue, mistake or not -- again, he can tell a lie from an error, but does not make the distinction in practice (142-146). Intention is "morally irrelevant" (155).

8. 7 is when the idea appears that one should not lie because it is wrong in itself, supplanting the idea that one should not lie because "you get punished" (168-9).

9. The interrogatory is completely verbal, as regards lying. It is possible that we have décalage here -- the child's verbal behavior lagging some years behind his situational and perceptive behavior (184-5).

10. 7 is when punishment ceases to be regarded as expiatory and becomes retributive -- to even up the score (201, 226-7).

11. Between 6 and 8, equality of treatment becomes the dominant part of distributive justice, overcoming the more primitive idea of unconditional obedience (278, 284-5).

12. Piaget links the development of a sense of justice to peer group socialization, rather than emulation of adult example.

VI. Play, Dreams, and Imitation in Childhood

1. Around 7 or 8, imitation ceases to be egocentric and, frequently, unconscious, and begins to become deliberate and purposive, taking its place in intelligence as a whole (72).

2. Imitation changes character in three basic ways around 7-8.

    a. Imitation becomes detailed, involving analysis and reconstruction of the model;

    b. The child becomes progressively aware that he is imitating -- he separates reality from the ego;

    c. The child, rather than imitating because of failure to differentiate himself from his environment, or for some immediate satisfaction, begins to use imitation as an aid to the fulfillment of needs; thus imitation is controlled by reflection (78).

3. Appearance, between 5 and 7, or games with rules — social games (142).

4. Symbolic games diminish after 4 or so, to be replaced by, or transformed into, games with rules (146).

5. Assimilation and accommodation, between 4 and 7, tend toward equilibrium, but achieve it only in the framework of some configurations -- bound up with immediate experience (243-4).

VII. The Construction of Reality in the Child

1. During the transition from sensorimotor thought to the higher levels of thinking, the child is less advanced on the verbal plane than he is in action -- this is décalage (361).

2. The preconceptual child is both

   a. unable to take another point of view than his own, and

   b. extremely suggestible, amenable to molding his peer group or adults in his deeds and utterances. This is the effect of the antagonistic operation of assimilation and accommodation (363).

3. Development is constantly spurred by the need to go beyond the self, to account for other viewpoints, in order to be able to communicate (366-7).

4. Three processes are involved in the development of object constancy:

   a. Accommodation of organs which makes it possible to foresee the reappearance of bodies.

   b. Coordination of schemata which make it possible to endow each of these bodies with a multiplicity of interconnected qualities.

   c. Deduction peculiar to sensorimotor reasoning which makes it possible to understand displacements of bodies and reconcile their permanence with their apparent variations (371).

5. The preconceptual mind seeks satisfaction at the expense of truth, of consistency and logic. (Through the social process, satisfaction is bound up with truth and logic. Through physical

experience, trial and error, and maturation of the brain and sense organs, the sort of conceptions involved in logical thought become possible. The first process provides the motive; the second, the means.) (Page 384, also a little speculation).

6. From 2 to 7, the child meets and overcomes, on the plane of preconceptual thought, all the obstacles which he encountered on the plane of sensorimotor thought from 0 to 2 (357-8).

VIII. Logic and Psychology

1. Appearance of true reversibility and object constancy on the plane of thought (13-14).

2. Development of a logic of classes and relations, the relation of seriation, inclusion, multiple characteristics (15).

3. Dependence on concrete data continues -- conservation of weight follows conservation of substance by a couple of years (17).

IX. The Growth of Logical Thinking from Childhood to Adolescence

1. Appearance of concrete operations (internalization of actions plus their gradual integration into reversible systems) around 7 (p. 7).

2. Efforts to eliminate contradiction or confusion in explanations begin to appear around 7 (28).

3. Children begin to assign multiple attributes to objects, along more than one dimension, to make physical explanations (28).

4. Kids start to be able to compare and seriate objects, though they are generally unable to pick the proper variables for solving the problem at hand (49-50). Nor can they control experiments (71-73).

5. Or, if they do reach a deduction or generalization, they can't explain it, necessarily (96-7).

6. In the colorless chemicals experiment the child of 7-7.6 does not make permutations -- he tries each with g, or all with g, but not 2 or 3 at a time.

7. In a weight-lever-fulcrum experiment, the child can perform operations on weight and distance, but only on a few states -- otherwise he gets confused (169-171).

8. Thus children at this age can rationally discover correspondences, but their explanations are still syncretistic, and their attempts at coordination are very reminiscent of juxtaposition.

X. Psychology of Intelligence

1. Through the process [illegible] egocentric and intuitive thinking, the child ignores some things (inability to decentrate). But, simply because he wants to operate effectively, he must learn to take account of as many aspects of the situation as possible. Ignored relations trip him up. Felt contradictions cause dissonance. Every detour he makes impresses upon him another point of view. He learns by experience (138-9).

2. Conservation of a whole begins to take the form of a logical certainty rather than a probable induction (140).

3. Deduction begins slowly to replace mental experiment (140).

STAGE I. UP TO 4 OR 5 YEARS OF AGE

Child's Conception of Number

1. Nonconservation of continuous quantities (5-13).

2. Nonconservation of discontinuous quantities (25-29).

3. 1-1 correspondence is lacking -- compressing a group of objects reduces their number -- "there are less of them" (43-44). In fact, the child has no notion of number -- he just fails to differentiate between number and space occupied (48).

4. The child's incapable of duplicating a given number of objects -- he merely tries to match their general appearance (86-87).

5. Children can neither seriate a set of objects nor make a 1-1 correspondence with an already seriated set (101).

6. In ordinal correspondence -- picking equivalent objects out of two series (like finding the third-from-smallest), which are not necessarily arranged in order -- the child uses no system at all -- he picks completely at random (106-108).

7. When trying to seriate ten sticks of increasing length into a staircase, the child tends to take them in any order, put their tops in a staircase pattern, and ignore where the bottoms are (124-126).

8. In a series where each object is as many times as long as the first as its ordinal value (object #2 is twice as long, #5 is 5 times as long, etc.), the child does not know how to find how many times card 1 goes into card n (135-136).

9. If given a lot of brown beads and 2 or 3 white beads (all wooden), the child says there are more brown beads than wooden ones. He can't think simultaneously of the whole and the parts (brown and white beads). A whole can't be divided into two parts and still retain its identity as a whole (171-174).

Child's Conception of Space

1. The child is unable to distinguish between figures that he can only touch and not see, except on simple topological bases -- open vs. closed. He does not explore the object -- he grasps it only once or twice. And since action is what leads to imitation, and imitation is what leads to images the child cannot draw or recognize the object (25).

2. The child's representation of visual objects (like a drawing of a man), observe topological relations (proximity, separation, order, enclosure, continuity) only in simple shapes, or with small numbers (49).

3. In copying geometrical figures, the first distinction is between open and closed figures, then the other topological relations are observed. After that, straight and curved sides begin to be distinguished.

4. The child is unable to reproduce a series of objects. He can only coordinate pairs -- put two objects in their proper relation (83-88).

5. The child cannot tie a knot, and can't recognize a knot if it is tightened or loosened a little (108-113).

6. Questions concerning subdivision of a square or line down to its final elements are not understood by the child (128-129).

7. The child cannot construct a straight line out of a series of objects -- he has no idea what constitutes a straight line, in the sense of a symbolic image going outside the field of perception.

8. The child is unable to make geometrical drawings at all.

9. The child has no idea of a shadow projection. He describes the object as he knows it is, regardless of the shadow's appearance (197).

10. The child has no notion of the surface of some water in a jar. He draws a scribble without boundaries, sometimes even going outside the jar (384-387).

11. Placing a doll on a model terrain, in the same spot as the experimenter places a doll on an identical terrain -- the child puts the doll in a similar "ground" observing topological relations like proximity, enclosure. Left-right, before-behind relations are not considered. If the child's model is rotated, he pays no attention to the changes of perspective and reversals of relationships which that requires (423).

12. Copying the layout of a model village -- the child observes no spatial or numerical correspondence; at best he copies a few proximities. But he may end up with twice the number of objects in his copy as are in the original, all in one corner (430-431).

The Child's Conception of Geometry

1. When a child tries to draw a map of his neighborhood, it is found that he takes no account of real distance, nor of the spatial relationships between more than two objects (7-11).

2. Copying a tower made out of blocks -- the child's tower is supposed to be the same height as the model tower. Stage I children use no measurement, only visual estimates. And it is not height which they pay attention to, but only vague similarity of detail. As they approach Stage II and begin to be concerned with height, they compare only the tops of the towers, not their relationships to their bases, which are on different levels (33-40).

3. The distance between two objects is not conserved if a screen is interpolated between them. The children think that the two objects are closer together if something is put between them, and become closer yet as the intervening object(s) take up more room. If one object is on a higher level than the other, the children say it is farther from the object beneath to the object above than it is the other way (73-75).

4. If shown a straight stick and a wavy stick, the Stage I child says they are equal if the far end points are aligned -- he pays no attention to the near endpoints, nor to the difference in shape (94). If two straight sticks (equal in length) are aligned, and one pushed ahead a little, the Stage I child says that one is longer, being unable to decentrate from the endpoints (95-96).

5. Measurement of the length of a zigzag paper strip by means of iteration of a very short strip is impossible at Stage I. The solution involves a concept of subdivision (of the broken line into units equal to the short strip) and orderly change of position (moving the small strip so that each measurement begins where the last one ended), which are not differentiated enough in the child's mind to be complementary. "Steps" are arbitrary in length, if they exist at all -- the child often simply runs his finger along the line (117-123).

6. When asked to duplicate the journey of a bead part way along a string, the children merely align the arrival points, and do not regard points of departure at all. Measuring instruments are used only to verify the alignment of points of arrival, even if the beads started from different ends of equal, parallel, and aligned strings (131-137).

7. The child is unable to put a point on a sheet of paper in the same position as a point on another, identical sheet of paper. They make no attempt to measure, and instead make a purely visual estimate (156-157).

8. Children are unable to copy an angle, except by visual measurement (174).

9. In copying a triangle, the child works entirely by guesswork, and makes no measurements at all (185).

10. Children do not understand the problem when asked to add up the angles of a triangle (196-197).

11. The geometrical loci of a circle and a straight line are beyond children at Stage I, since they have no real notion of distance (210).

12. Children are unable to conceptualize a mechanical path of movement before it occurs (229).

13. Measurement of area (by superimposition of smaller units) is impossible at this stage. Children do not conclude from seeing that it takes more small units to cover area B than area A, that area B is larger, because the middle term is not conserved, and thus their thinking is intransitive (292-294).

STAGE II. 4 or 5-7 YEARS OF AGE

Child's Conception of Number

1. Conservation of continuous quantities within narrow proportional limits (13-16).

2. Conservation of discontinuous quantities within narrow proportional limits — but the child thinks that two strings of beads, made from the supposedly unequal amounts of beads in each glass, would be of equal length (29-32).

3. 1-1 correspondence is intuitive, and cannot cope with large perceptual changes, such as compressing or expanding the row (44-47), but the ability to do so arises around 6 years of age (47-49).

4. When asked to duplicate a number or set of objects, the child becomes very meticulous, but is still thrown off the track by perceptual alterations. He is not yet capable of abstract, reversible coordination (87-89).

5. The child becomes able to seriate a set of graded objects, and to make a correspondence to an already seriated set (100-102). Seriation and correspondence are intuitive and perceptual, and the approach is trial-and-error (104).

6. If told to pick equivalent objects out of two rows, children count from the end. (They also make a consistent mistake. If they are to pick object #5, they count up to it, but not including it -- they count through 4, which is the instrumental number. Then, on the row where they must find the fifth object, they count up to 4 again, and then say that it is the one they want. Piaget explains this by saying that 4, being the number on which the child is relying to find the proper object, remains conscious while its relationship to the proper object does not.) If the series is disarranged, number is conserved, but efforts to find a corresponding object are random (110-118).

7. Children can arrange sticks into a staircase (a series of increasing length) after trial and error -- it is hard for them to remember that something is "larger than" the sticks already seriated, and "smaller than" the sticks not yet seriated (126-129).

8. In an incremental series (card #2 is 2 times as long as card #1, card 5 is 5 times as long as card 1, etc.), the principle of increment is understood, as well as the relation of size to position, but he does not apply this to numbers larger than four. He tries to divide the card mentally to see how many times card #1 will fit in. Thus he does not possess true cardination or ordination (137-138).

9. If a child is given a lot of brown and few white beads, he can answer the question "are there more wooden beads or brown beads?" by intuition. He has to make an effort to conceptualize the brown beads twice, once with the white beads, and once without, before the answer becomes operational (175-177).

Summary -- The child at this stage is capable of ordination and cardination, but not operationally. He solves problems by trial and error. He does not grasp, for instance, that a given position in a series necessarily corresponds to an exact cardinal value; he does not keep position and value both in mind at once (150-152). He cannot determine, in any operational way, a cardinal value by reference to an ordinal. (How many times larger than card #1 is card #5?), or an ordinal value by reference to cardinal (How many stairs have you climbed if you're on step #10?). Being able to determine that the nth stair is the last term of a series of n stairs is psychologically operational, not intuitive (152). Likewise, the invariant relation of a term in a series to the one preceding it and the one following it cannot be borne in mind, independent of perception, without an operational construction whose most important characteristic is that it is reversible (154-155).

Through physical experience, the child at Stage II gradually begins to behave in object constancy, conservations equivalence, the invariant relation between ordinal and cardinal numbers in a series, and all the other things he calls obvious by Stage III (204-205, 223).

Child's Conception of Space

1. The child's haptic perception begins to recognize some clues like angles, curved edges, and to search actively for such clues (29-30).

2. Drawings of a man take more complete account of topological relations. Perspective and distance are not observed (51).

3. In drawing geometrical figures, the kid differentiates euclidean shapes as to proportion of sides, number of sides. The oblique line (as in a rhombus) is mastered (60-80).

4. The child can copy series of objects by correspondence, but cannot put his series in reverse order to the series he is to copy from, nor can he build his copy into a circle, nor can he rotate his copying efforts 90° so that left-right becomes up-down. By the end of Stage II, the child is able to transpose his copying into a circle (88-96).

5. The child learns to grasp the dynamic transformations of a knot-loosening or tightening (118-123).

6. Questions on the idea of a point and of continuity. The child at Stage II is dominated by static perceptions. Thus, when asked to draw the smallest possible square on a sheet of paper already containing a square, they edge downwards bit by bit, rather than extrapolating from the square they see to a very tiny one -- successive approximation when asked to subdivide a line ultimately, they wind up with a line about 2 mm long and say it can't be divided any further. If you ask him what the shape of the ultimate end product of the subdivision will be, you find that it will be the same shape as what you started with -- for a square, a square; for a line, a line, etc. And the child insists that it is impossible that a line, a square, or anything else, can ever be made out of points and be continuous at the same time. All these things are explicable by reference to the Stage II child's heavy reliance on perception, and his inability to conceive of something (i.e., a square) as one of a large number of squares of varying size, or as made up of imperceptible elements, like points. Points are not conceived by the child -- his ultimate elements all have shape. Since a point can't be perceived it is not "real," does not exist (130-138).

7. During Stage II, the child learns to construct a straight line, parallel to the edge of the table, or against a neutral ground, but not obliquely to the edge of the table. At Stage IIB, a line can be constructed oblique to the edge of the table, by the operational construction of sighting along the line. This is operational because it involves imagining all possible points from which to view the line, and finding the best one for determining whether the line is straight (165-170).

8. At Substage IIA, the child cannot draw a figure in perspective (i.e., a circle tilted away from the child to make an elipse is still drawn as a circle). Representation of perspective demands awareness of a point of view, and of its effects on the object's appearance, and of the fact that the observer and the object are in the same space which extends beyond them both (176-178).
At Substage IIB, the kids are usually able to match the perspective in which they see the object with the correct drawing in a series of perspective drawings of the object, though their own drawings tend to compromise between what they see and what they know the true shape of the object to be (182-184).

9. The child understands that there is a relation between the orientation of the object and the shadow it will cast, but he does not generalize this. He says that the shadow of a pencil end-on will be a small circle, but he assimilates anything short of that to the schema of a pencil seen full-length (197-199).

10. In an experiment with a 3-dimensional landscape model, where a doll is placed in a different position than the child and the child is asked

what the doll sees, the child at Substage IIA merely reproduces his own viewpoint. But he is aware that the appearance of the model will change if it is viewed from somewhere else -- he can put a doll at the point of view of a flat picture of the model. After the child himself has moved, he can reconstruct his previous perspective from memory. But to anticipate a perspective he has not yet seen involves decentering and virtual rotation of the model, which are beyond him (215-222). At Substage IIB, the child realizes that the view will be different from elsewhere, but he does not rearrange the internal elements, reversing left-right and before-behind -- these relations are still considered "realistically" -- as absolutes (223-233).

11. The child can't imagine what a geometrical section of a solid will look like before it is made. He draws the object as he knows it is, not according to any particular viewpoint, and tries to include everything, inside and out (251-255). At IIB, the kids represent the act of cutting itself as a simple straight line going down or across their generalized picture, and a little later, they begin to curve the line to try to reproduce the shape of the cut solid, while including other parts of the solid in defiance of the laws of projective geometry (255-258).

12. Rotation and Development of Surfaces -- at Substage IIA, the child draws an object (cube, cone, etc.) as only one salient feature -- a cube is a square, a cone is a triangle or a circle, whether the object is folded or unfolded. At Substage IIB, the child indicates unfolding in rudimentary ways -- using a line to indicate the direction of the unfolding. When asked to outline a piece of paper that could be folded into the desired figure, he draws the figure somewhat larger (299-80, 288).

13. Affinitive Transformation of a Rhombus -- using a pair of extensible tongs. At Substage IIA, the child gives the rhombus no definite shape -- he can't really anticipate the future shape of the rhombus. He does not conserve parallels, either. At Substage IIB, he still does not conserve parallelity or length of sides, but he does admit that the area of the rhombus will reach a maximum size and then begin to shrink again, though this change of area is assimilated to a concept of change in absolute size (308-313).

14. Similar figures and proportions Substage IIA -- the child cannot draw a similar triangle to one he is shown, either inscribed, circumscribed, or adjacent. There is no parallelism between corresponding sides, angles are not equal. Nor can the child pick one out of a number of triangles as similar to the model. At Substage IIB, parallelism begins to show up, especially with equilaterial or obtuse isosceles triangles, or if the enlargement of reduction of size is small so that corresponding sides are perceptually near each other. When parallelism is achieved, it is by successive trial and error.

Judgments of dimensional proportion are still primitive, as the child's greater error with rectangles shows (327-332; 343-346; 356-361).

15. Systems of Reference -- if children are asked where the surface of colored water in a jar is if the jar is tilted, their answers indicate lack of a frame of reference, the sides of the jar, or the horizontal on which the jar rests. The water is imagined, at Substage IIA, to move, but its surface is always parallel to the base -- thus as the jar is tilted, the water is represented as moving toward the neck; increasing in volume. Houses and trees are drawn as perpendicular to the slopes of hills, rather than as upright. At level IIB, the child draws some compromise between the tilt of the base of the jar and the horizontality, when asked to draw the surface of water in a tilted jar. He still does not relate to any frame of reference — he just draws it oblique to the jar. He also fails, much of the time, in making the water surface flat -- he draws a curved line. He puts the trees and houses vertically on the hillside at first, though he generally forgets and begins drawing them perpendicular again (387-401).

16. Placing a doll on a model terrain -- At substage IIA, the child takes account of relationships between the doll and 2 or 3 objects, or the model as a whole, usually putting his doll in the same absolute position, neglecting rotation of the model. If the experimenter's doll is placed next to a landmark, the child will put his doll next to the landmark regardless of rotation, and some will try to coordinate the left-right relations, though they do not succeed if the model is rotated. At Substage IIB, the child becomes aware that rotation reverses relationships. He can coordinate them, though only one at a time and only later multiplying them. This is an intuitive, not an operational process (424-425).

17. Copying the layout of a model village -- the children at Substage IIA do not use the board as a set of axes. They form simple relationships, mostly between two or three objects, but do not coordinate these with the rest of the objects. Distance is generally ignored. When asked to make drawings, Stage II children just put the objects in a line or a curve, sometimes trying to represent greater distance by drawing the object smaller, but they are generally unable to convey the idea of background. They also fail to maintain a consistent point of view in the drawings (432-436).

The Child's Conception of Geometry

1. When children are asked to draw a map of their neighborhood, or of how they go to school, they do not keep the landmarks in proper order, nor do they respect relations of distance (11-14).

2. Copying a tower made of blocks, starting from a lower elevation. The child at Substage IIA concentrates solely on manual transfer -- physically putting the two towers next to each other -- as a check of height. This is done in detail -- block by block -- as well as overall. At Stage IIB, they begin to use their bodies as a middle term, stretching their arms, or marking a point on their legs while their head is to represent the tower's top, etc. As they near Stage III, they begin using physical objects as common measures, though in a faulty, uncoordinated way. The middle term must be the same height as one of the towers, or it must look like the thing being measured. If it is too short, it is rejected, since these children cannot use the concept of a unit (40-56).

3. Distance relations. Children at Stage IIA can construct an overall distance between the separated objects, though they still claim that this distance will vary with the thickness of the screen between them. They claim that the distance is reduced by an amount exactly equal to the thickness of the screen. They still think that distance is asymmetrical if there is a difference in height. Distance is understood by these children as empty space. They have no idea of "common space" which can be either empty or filled (75-80). At Substage IIB, children think of distance relations as symmetrical despite differences in height, but do not conserve overall distance. Alternatively, they do conserve overall distance, but think that distance relations are asymmetrical. In the first case, distance is still equated with empty space, but the child is able to take the viewpoint of the two objects involved and thus sees that distance between them is the same both ways -- it is no longer bound by an egocentric schema of "forward" and "backward," or "far" and "near." In the second case, the child reasons that since the figures have not moved, the interposition of a screen does not alter the distance between them. But his consideration of reciprocal distance is still contaminated by dynamic considerations (80-83).

4. If shown a straight stick and a wavy stick whose endpoints coincide, the children say they are the same length until Stage IIB, when they realize that it would be further to walk on the wavy one, or that the wavy one could be stretched out full length (94-95). If they are shown two equal straight sticks, and one is staggered, they do not begin to get the right answer until Stage IIB, when their answers are still intuitive (198-200).

5. Measurement and comparison of two zigzag lines by using a very short strip of paper as a unit of measurement is impossible at Substage IIA. At Substage IIB, the child begins to understand the principle of unit-iteration, but they apply it in a preoperational way. The steps are of unequal length, or do not cover the whole line (123-125).

6. At level IIA, children cannot duplicate the partial movement of a bead along a string except by aligning the beads. At IIB, they begin

to become aware of the relations between the distance traveled and that which is left, and of the effect of having different or unaligned points of departure. Their understanding is intuitive, however, and when they try to measure, they wind up measuring the wrong part of one of the strings, or forget to mark the exact place where the bead rested against the ruler, etc. They are able to understand the operation invoked on a qualitative level, but are unable to apply it quantitatively. Qualitatively, they see that the length of the strings is subdivided into nesting intervals, and they are able to compare these intervals by measuring them but are unable to coordinate these understandings (137-142).

7. When asked to put a point on a piece of paper in the same place as a point on another, identical sheets of paper, children at Stage IIA make a purely visual estimate, sometimes aided by a ruler. At Stage IIB, most of them make one oblique measurement from the corner of the page, and try to preserve the inclination of the ruler when moving it from one sheet of paper to the other, but they have no way to make sure the slope will be the same (152-161).

8. When asked to copy an angle, children at Stage IIA make a guess only. At IIB they measure both lines, but have no way to measure the slope (176-177).

9. The best that kids at Stage II can do in copying a triangle is to measure all three sides without checking the angles at all; thus their triangle does not close properly (185-188).

10. The children see that the angles of a triangle (when cut out and put together) make a semicircle, but they are not sure that this will still be true if their order is changed until the end of the stage, and even then do not generalize the result to all triangles (197-198).

11. Children learn to handle the loci of a circle and a straight line inductively. They begin by being able to make an irregular circle, and to locate a midpoint between two points by visual estimate. But they do not generalize the midpoint in both directions, as a bisector. They begin generalizing toward infinity at each end, and toward continuity throughout (212-220).

12. Children assimilate the idea of a simple rotation to the static outline of the object -- they imagine that a rotating triangle will inscribe a triangle, etc. Complex motion is not grasped until Stage IIB, when they start making compromises in the proper direction. Constituent motions (for instance, rotary and linear, producing a cycloid) are frequently juxtaposed rather than combined (236-245).

13. Subtraction of smaller areas from a large one -- the remainder is judged smaller if the smaller areas are scattered than if they are all together. Sometimes the children will say that the remainder is equal for 3 small areas, in any position, but not for 4. This is articulated

intuition at work. "These results are especially instructive... because they show the almost imperceptible gradation from failure of all composition, through intuitive composition, at first simple and then articulated, to operational composition. Each new (subtraction which can be made from both areas, whatever its location) without disturbing the recognitions of equality marks a step forward in development, until the point is reached when the solution is generalized to all possible situations" (261).

14. Conservation of area through change of shape is absent at Substage IIA. "Area" is an abstract concept -- what the child notices is that the shape has changed, or that the area covered by the spaced out parts seems larger than the area covered by the parts compressed together. And even if the children see that the number of units is the same, they do not think in terms of fixed sites as a frame of reference (277-280). At Stage IIB, children proceed by trial and error, empirically, to eliminate some of their errors. The child's powers of composition can encompass changes of shape that are not too drastic, but beyond that limit, area is again not conserved (281-284).

15. Measurement of areas by superimposing small unit areas over them is still perceptual and nonoperational at Substage IIA. At IIB, the children admit that if it takes more small units to cover B, then B must be larger. They will also admit that the cards which covered B are equal to B in area, even when the cards are all spread out (295).

16. Subdividing areas -- concept of fractions. At Stage IIA, children can cut a cake in half, sometimes into quarters as well. When asked to cut the cake into 4 pieces, they have no idea of fractions as equal and exhaustive portions of a whole. They grasp this idea intuitively by Stage IIB. They have trouble dividing the cake into thirds or fifths, because they lack an anticipatory schema for what thirds or fifths should look like (312-320).

17. Doubling an area or a volume is impossible. Even with a line, the children do no more than make an arbitrary increase in length. When asked to double a square, they increase each of the sides a little (339-342).

18. The child at Stage IIA does not understand compensation of dimensions in volume. He compares two blocks built of small cubes only in terms of the longest dimension, which he refuses to exceed, even if the other dimensions of his block are much smaller than the corresponding dimensions on the original block. By IIB, children will exceed the height of a model to compensate for a smaller base, but will not exceed it enough -- they approach the problem intuitively (360-370).

STAGE III. 7-11 YEARS OF AGE

Child's Conception of Number

1. Necessary conservation of continuous quantities (16-24).
2. Necessary conservation of discontinuous quantities (32-40).
3. The child gains an abstract notion of correspondence, and can duplicate a set despite changes — i.e., he has reversibility (89-92).
4. The child is able to seriate a set of graded objects by use of logic (89-92).
5. When told to pick corresponding objects in disarranged series, children first arrange the whole series and count, and, later arrange the series only up to the number they want (119-121).

Child's Conception of Space

1. The child's haptic exploration becomes methodical and parsimonious. He considers and rejects possibilities as he goes along (21).
2. "Visual Realism" in drawing -- tries to take account of perspective, distance, and proportions -- projective and euclidian relations are beginning to emerge (projective relations are those between figures, relating them according to points of view and perspective. Euclidean relations are those among figures with relation to a framework or coordinate system, conserving not only shape, but size.)
3. The child slowly learns to reverse the order of a series, by trial and error (98).
4. When you ask a child about ultimate subdivisions of a square, a line and a triangle, you find that he has mastered the operations of seriation and subdivision, which have become functionally reversible. But these operations break down beyond the limits of the visible and tangible, since concrete operations are not hypothetico-deductive in character -- the children still have no conception of infinity, until Stage IV (11-12), though they begin to talk about "millions" around the age of 10 1/2 (140-145).
5. Children can represent perspective more accurately than before, though they still make errors. For instance, they do not draw the cross ties on a railroad closer together as the railroad recedes into the distance until late in Stage III (Substage IIIB). The reason is that they lack a real extensive quantification, or a sense of real continuity -- the same problems which prevent them from comprehending indefinite

subdivision or continuity in experiment 6 (187-188). At Substage IIIB, the child has a sense of continuity and of extensive quantification, and his drawings are much more accurate than before (188-192).

6. The child arrives at a proper explanation of foreshortening as a function of tilt (199-200).

7. The child makes an attempt at reversing left-right, before-behind relations, but can't do it comprehensively. He does better with before-behind relations, or takes account of only one relation and ignores the remainder (242-246).

8. The child correctly draws a geometrical section of the object (258).

9. The child, when asked to draw a piece of paper with which one could make an object, draws the object in perspective -- they are trying to represent the act of unfolding (289-291).

10. Affinitive Transformations of a Rhombus -- the child now begins to try to explain the change in area as a change in the height-width ratio, though not explicitly. He also realizes that opposite sides must be parallel for symmetry (313-315).

11. Similarities and Proportions -- Parallelism of corresponding sides is discovered as a necessary fact, as is equality of corresponding angles (which is actually the same thing -- for the child, an angle means two lines coming together). There is a beginning of proportionality, as the more and more successful drawings of similar rectangles show. This proportionality is not fully grasped until Stage IV (332-342; 346-352; 361-369).

12. When asked to draw the surface of water in a tilted jar, the child first discovers horizontality when the jar is lying on its side, and the water level is parallel to the sides. During all of IIIA, the child finds the horizontal and vertical through trial and error, and by IIIB, he admits their logical necessity (401-415).

13. Placing a doll on a model terrain -- rotation no longer has any effect upon the child's judgments (425).

14. Copying the layout of a model village -- the child's drawings now have a definite point of view. His physical copies of the model take account of relationships of objects with the board and with each other as well. The only errors are in making exact measurements, or in making reductions to a smaller scale. Also, if an object on the model is moved and the child has to copy the displacement, he resorts to a series of approximations. Not until IIIB (around 9-10 years of age) is he able to take such displacements in stride (432-444).

The Child's Conception of Geometry

1. Children begin to coordinate landmarks, positions, and distances in their drawings of their neighborhood, but they tend to build up two or three areas which are internally correct, but incorrectly related to one another, based upon the child's habitual journeys through town (15-18). By level IIIB, two dimensional coordinates are preserved, though proportion is not perfect.

2. Copying a tower made of blocks. At Stage IIIA, the child still can't use a unit -- his common measure must be the same length or longer. He has achieved operational equilibrium, but only qualitatively, through a synthesis of parallelism, horizontality, and conservation which enables him to set up logical criteria of equal height in his mind (57-58). A short measure is used, finally, at IIIB, where unit iteration is developed (62-63).

3. Distance relations -- distance is conserved, again "because the objects have not been moved" -- a fact which younger children were aware of, but did not use. The child has developed a schema of space which refers to fixed sites, which are separated by an interval with a certain rectilinear length (83-88).

4. When shown two straight sticks of equal length, one of which is staggered, these children say the sticks are still equal. Their reasons are that "the stick don't grow," or "you added a little at that end, but took off just as much at the other end" -- which is a clear example of the child's beginning to think in terms of "sites" which may be filled or vacant (100-102).

5. Two zigzag lines can be accurately compared in length by using a short strip as a unit measure (126-127).

6. Children are able to measure and duplicate the partial journey of a bead along a string, as long as their ruler is longer than the bead's journey. Otherwise, they improvise supplementary lengths added to the end of the ruler, and do not think to move the ruler to a successive position until Stage IIIB. At IIIA, they lack the operational concept of a movable unit (142-146). Conclusion -- two operations are involved-- order and change of position, and subdivision. The first determines asymmetrical relations between points on a line, such as order, direction of measurement, etc. The second determines nesting series of equal intervals along a line. Until these operations are combined, there may be conservation of length, as long as the child is old enough to deduce from the fact that none of the points have moved the conclusion that none of the intervals have changed, but measurement and comparison cannot take place (146-149).

7. When asked to put a point in the same place on a second sheet of paper as on a first, kids realize the necessity for two-dimensional measurement, and coordination of the measurements that are taken. By trial and error they discover that the two measurements should be perpendicular. At Stage IIIB there is no hesitation (165-168). There is no time lag between successful measurement in two or three dimensions -- the same operations are used, but an extra direction is added (169).

8. When asked to copy an angle, children at IIIA can find no way to measure the slope. They measure all the distances along the existing lines, but can only try to gauge the slope. They do not learn to drop a perpendicular until Stage IV (179-184).

9. At Substage IIIA, children try to copy a triangle by holding the ruler at a constant slope. At Substage IIIB they learn to measure the height, drawn perpendicular to any of the sides, to control the angles adjacent to that side (188-191).

10. In dealing with cutout angles of a triangle, children at IIIA do not grasp that the size of the angles is mutually dependent, but, seeing that the angles of all different shapes of triangles make 180°, they feel it must be a constant and try to find out why -- empirically, and by trial and error. It is not until Stage IIIB that the law is generalized operationally (198-203), though it is still not considered operationally necessary.

11. Children solve the loci of a circle and of a straight line. Infinity of the bisector is accepted, not as an abstract concept, but simply as an example of unlimited iteration (222-225).

12. Mechanical motion is considered as the multiplication of two kinds of motion, leading to educated guesses at Stage IIIA, and empirical (not operational) solution at IIIB (246-253).

13. Operational conservation of area, in the face of change in shape. The child here relies on his understanding of transformations as such, and does not need to compare any figures. This conservation appears at the same time as that of distance and length (topics 3-5, this section) (284-286). Area outside a closed perimeter is not conserved until Stage IIIB. This is probably because it is perceptually more difficult (286-291).

14. Measurement of an area by superimposing smaller units over it is grasped at once (295-296).

15. Subdivision of a cake into even fractional parts -- kids at Stage IIIA have no trouble dividing a cake into 3 parts. At IIIB, they can easily make divisions into 5 and 6 parts. Success must be preceded by trial and error at the previous substage, since representation cannot foresee the possible unless guided by action (320-334).

16. Doubling an area or a volume -- (length is doubled correctly). At level IIIA, the children either change the shape by doubling one dimension, or get the wrong answer by doubling all of them. At Substage IIIB, the child realizes that doubling both sides gives the wrong answer, but does not know how to get the right answer. The right answer involves coordinating area and length -- their relationship is still too subtle for him (342-350).

17. The child understands compensation of dimensions in a three-dimensional framework. He will alter his dimensions as much as necessary to get the same number of bricks into his block. But he thinks of it as a number of bricks, not as a volume of space, as can be seen by the following: if the bricks are immersed in water, and their arrangement is changed, the child thinks that this will change the level of the water. Volume, in the sense of space occupied, is not conserved until Stage IV (370-381).

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Changes in Learning Processes in the Late Preschool Years[1]

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> "...Then it is safer that the brain be rightly consolidated before it begins to sustain labors: in an infant the whole cranium is scarcely closed, and the brain is not consolidated before the fifth or sixth year."
>
> Comenius, The school of Infancy.

> "There is no absurdity so palpable but that it may be firmly planted in the human mind if you only begin to inculcate it before the age of five, by constantly repeating it with an air of great solemnity."
>
> Schopenhauer, Essays.

Much evidence suggests that there are important changes in children's learning, or in qualities related to their ability to learn, during the age range extending roughly from five to seven years. This evidence may ultimately lead to some significant basis for judgment about two issues which are much discussed in American education -- one issue the issue of readiness, whether it is necessary or useful for educators to take precautions about readiness for such subjects as reading, the second issue having to do with compensatory preschool education, its aims, its approach, its evaluation. Given the theoretical and practical issues which cluster at the entranceway to schooling, all research material suggesting cognitive change in the child between five and seven years deserves careful probing.

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The best-known American evidence of transition in this age range consists in demonstrations of children's changing reactions to the two special variants of discrimination learning: transposition and reversal shift-nonreversal shift procedures. Because these changes move the child from an animal-like to an adult-like pattern of performance, and because they occur at a time when children characteristically begin to name relationships between stimuli, the changes have been cited in support of the argument that mediation is the basis of human conceptual thought. Presumably, children begin to apply names like "larger than," "middle-sized," etc. in the age range from five to seven and, through the mediation of these naming patterns, their problem-solving begins to show signs of conceptual activity.

If one means to be exact in the use of the term 'mediation' -- the precaution is important -- then there is an increasing body of evidence indicating that the hypothesis will not do. Exactly speaking, the mediating response is a member of the family of "pure stimulus acts," or response-producing stimuli, which behavior theorists have proposed as mechanisms to underlie terms like "expectancy," "symbol," or "concept." The mediating response is assumed to be an implicit response, not necessarily verbal but usually supposed to be, which the child makes to an originating stimulus. The implicit response produces an implicit stimulus that may lead the child by its habitual linkages to a final overt response never connected to the originating stimulus.

In effect, to suppose for the child this intervening implicit response implicit stimulus link is to suppose for him a kernel of central choice. He now has an option inside which can prevent him from being "stimulus bound:" faced with a stimulus, he does not have to do what he did the last time he saw it. Indeed, if one chains together many links of mediating responses, as Osgood and Berlyne have done, one can produce a central spider web of mediating responses sufficient to account for the complex choice systems underlying language and thought. Unhappily the extended central networks of neobehaviorism, like the elaborate central structures of psychoanalysis, can explain a great many phenomena only inexactly and in a post hoc fashion. However, the one-stage mediational assumption of the Kendlers (1962) and Reese (1962) is a cautious supposition and a reasonably testable one. It has been tested, and the gathering evidence seems more and more to suggest that the child's progressive sophistication in language between five and seven is not the cause, but is rather the correlate, of his progressive sophistication in learning.

The hypothesis of mediation, as is characteristic of most stimulus-response explanations, was tailored to fit the data of learning experiments, as is true of a rival attentional hypothesis (Zeaman and House, 1963) now favored by many. However, it is possible that the age changes in learning to which these rival hypotheses address themselves cannot be fully understood by an examination of the learning literature alone. To understand these age-changes in children's learning, we may have to look far beyond what is nominally considered the learning literature.

If one examines the developmental literature at large, the over-whelming fact emerges that there are a large number of behavior changes reported in children between ages five and seven, changes not only in learning, but in perception, learning, physical growth, pathology, emotion, and the factor structure of intelligence. While some of these transitions might be harnessed with the learning phenomena under a mediation or observing-response hypotheses, a good many others seem to fall outside the scope of either hypothesis.

The scope of the evidence, and several strong theoretical assertions which have been offered about this age range, would suggest that the developments within discrimination learning are part of a wide-ranging change in the child. We will not have time to review all of the developmental evidence today. Some of the empirical and theoretical material relating to this age range has been reviewed previously (Kendler & Kendler, 1962; Reese, 1962; White, 1965, 1966a, 1966b). Instead, we will be concerned to sketch out those facets of the evidence which might be brought to bear on understanding the relationship of these data to the onset of schooling and its influence upon the child's life.

When study after study in the United States, Britian, Switzerland, and Russia turns up evidence of behavior changes in the child in the age range during which he typically begins school, our interpretation of this material must envisage two alternatives -- first, the possibility that the child's entrance into schooling, presumably a major event in his life in all Western Societies has important effects upon him and changes his reaction to any kind of psychological experiment with which he is confronted -- second, the possibility that the observed changes reveal a profound developmental change in the child himself which is a precondition for schooling,.acknowledged in society's historical decision to begin schooling at six.

Viewing the alternatives in this way, we can seek to kind evidence which, in one way or another, controls for the effect of schooling on change in the child in this age range.

First, we can ask if there are physical changes in the child at this time which might plausibly be related to changes in his cognitive abilities.

Second, we can ask if other cultures have practices or beliefs which seem to acknowledge significant change in the child at around six years of age.

Third, we can ask if the experimental material of Western, research-producing societies is replicated in studies of children in cultures where they are not placed in school.

We begin, first, with evidence related to the physical growth of the child. Figure 1 is taken from Tanner's book Growth at adolescence (1955a). It illustrates the oldest known longitudinal material on physical growth, measurements made by Count de Montbeillard of his son over the years from 1759 to 1777. Discussing the figure, Tanner calls attention to an accelerative component appearing at around age 6 and indicates that this is representative of an acceleration in growth which, in the anthropometric literature, has been referred to as the "juvenile growth spurt," or the "mid-growth spurt."

The next figure is taken from Zubek and Solberg's (1954) text, and shows averaged curves of growth for a larger sample. In this figure, the mid-growth spurt is clear in the weight data, particularly for the boys, but does not appear in the height curves.

In general, the mid-growth spurt has been of interest to anthropometrists because they have seen that spurt as one of several indications that the physical growth of the child may have to be seen as a phasic or cyclical affair. In the early part of this century, Robertson (1915, 1923) was extensively concerned to establish the proposition that physical growth occurs in autocatalytic cycles. Chemical products accumulating during one phase of growth are presumed to finally catalyze, trigger off, another phase of growth, thus making physical growth a saltatory rather than continuous affair. In the course of Robertson's argument, he analyzed weight growth curves for an Australian working class sample of children. He proposed that the onset of a major new cycle of growth began at age 5, calling that cycle the "Juvenile cycle."

In 1921, Bird Baldwin published a research report and literature review on physical growth as Volume 1, Number 1 of the University of Iowa Studies in Child Welfare. This monograph, an immensely careful effort, notes persistent evidence of perturbations in the growth records of children at five or six years of age:

> "The individual growth curves for pre-school children show significant but unexplained fluctuations at five or six years of age in individual growth curves in height, weight and breathing capacity."
>
> (Baldwin, 1921, p. 71)

Baldwin noted only the instability of growth at this age, but offered no more exact description of the specific growth variables defining the instability.

In 1935, Howard Meredith published another Iowa monograph, titled "The rhythm of physical growth," which analyzed age changes in eighteen standard measurements applied to males between one and eighteen years of age. As his title implies, Meredith was concerned with the issue of continuous versus saltatory, or phasic, growth patterns in these dimensions. Meredith proposed that his eighteen measurements conformed to four different patterns. Two of those cyclical growth patterns "broke" around age six.

One of Meredith's types fits the data pictured in the lower right and left figures of Figure 3. Meredith describes the patterns as follows:

> "There are three pronounced cycles for bi-condular diameter of left femur and left humerus. The first cycle spans the years from birth to six, the second reaches from six to eleven, while the third extends between eleven and eighteen."

Meredith's description of a second growth pattern, one applying to the lower right left figures of Figure 4, is as follows:

> "There are three roughly convex cycles between one and one-half months and ten years for the four measurements of skin and subcutaneous tissue. The four minima of these cycles occur at one and one-half months and at approximately two, six and ten years."
>
> (Meredith, 1935, pp. 116-117)

Further growth curves showing the form of the second described cycle are given in the Figure 5.

Meredith's analyses, then, are supportive of an acceleration in growth, a mid-growth spurt, occurring at about six years of age in some growth measures but not at all, or not equally, in other growth measures. In a subsequent discussion of the mid-growth spurt, Tanner (1947) suggests a definition of the dimensions participating in the spurt.

The next figure, Figure 6, is taken from Tanner's article, and it pictures the mid-growth spurt in females as it emerges in measures of bitrochanteric diameter (hip width). The lower figure shows the spurt most clearly. Figure 7 is taken from the same article and illustrates a differentiation suggested by Tanner. He suggests that by and large measurements of length do not reveal a mid-growth spurt very clearly, but that measurements of breadth do. It will be noted in the upper figure that the three curves reflecting length measurements do not show much sign of a mid-growth spurt, while in the lower figure all three breadth measurements do show such a spurt. My own impression, based on examination of these and other data, is that signs of a mid-growth spurt are more regularly revealed by measures of weight and width than in measures of height or length of body parts, but there are exceptions.

These indications of a mid-growth shift reflected in anthropometric dimensions of the body have only vaguely been linked with underlying physiological changes during development.

Possible changes in part processes are suggested by an analysis of the growth rates of four tissue types set forth by Scammon in 1930. Figure 8 shows a set of growth trends derived by Scammon for four groups of body organs at different ages, groups classified as lymphoid, neural, general, and genetal types of tissues. For each tissue group, weight at 20 is taken as 100%, weight at birth as 0%. Thus, these are curves of relative growth rate. It will be noted that the weight of neural type tissue reaches 90% of asymptotic value at age 6; it will also be noted that a large acceleration of lymphoid growth also begins at that age. The data on neural type growth may be the basis for an undocumented assertion which one meets with occasionally in the literature, to the effect that the growth of the nervous system is substantially completed by age 6.

The next figure, Figure 9, also taken from Scammon, pictures component curves representing the separate growth of the six organs from which the neural type of growth was synthesized. It pictures relative weight increments on the 0%-100% scale for whole brain, cerebellum, pons and medulla, eyeball, head circumference, and weight of the pineal body.

Recently, Dustman and Beck (1966) have reported results of a study of visually evoked potentials drawn from a cross-sectional sample of 215 subjects ranging from one month to 81 years of age. The right graph in Figure 10 pictures the amplitude of evoked occipital potentials over age; the three separate lines indicate measures of amplitude for three time intervals after stimulus onset. It will be noted that a peak reaction is found at age 6 in these data. The left graph of the figure compares the records of three individual subjects aged 6, 16, 60. The most pronounced reaction, represented by the solid line, is that of the six year old subject.

The physiological or psychological implications of Dustman and Beck's data on evoked occipital potentials are not at all clear; for the moment, we can only align their data with Scammon's data on neural tissue growth. Scammon's data in a structural way, and Dustman and Beck's data in a functional way, both suggest that age 6 may be a significant period in the development of the nervous system.

Scammon's data on the development of lymphoid tissue are paralleled by other data in this period; particularly interesting are a number of reports of change in endocrine function -- for example, the following quote from Tanner:

> "The level of the fasting blood sugar has been investigated in cross-sectional studies, the blood being taken in the morning, after the subject fasted since the previous night. The level appears to rise about the time of adolescence, no marked sex difference being present... Very interestingly, there seems to be another period of relatively high blood sugar from age 5 to 7, that is, coincident with the mid-growth spurt. It remains to be seen if these results are confirmed in longitudinal studies."
>
> (Tanner, 1955a, p. 111)

This change in blood sugar level seems related to a break in the growth pattern of the Islets of Langerhans in this age range. At this time, also, there appears to be fragmentary evidence suggesting a modification of adrenal secretion, changes in pituitary action (Tanner, 1955b), and a beginning acceleration of estrogen secretion (Tanner, 1955a, p. 120).

Let me now summarize the material on physical growth. Within the anthropometric literature, there is evidence for a mid-growth spurt occurring in the age range from five to seven, evidence from a number of studies of physical growth. By and large, this evidence seems to be seen most clearly in measures of weight or indices of body breadth. What physiological processes might underly such a spurt is not clear; there are several indications that these exterior changes are associated in time with the growth of neural tissue and with suggestions of alterations in various endocrine secretions.

It is interesting, in the light of the growth changes just considered, that Bloom (1964) has argued that a stabilization of intelligence occurs in the child at around seven years of age. Bloom's argument was constructed from an analysis of the intercorrelations among longitudinally-gathered IQ scores, but there are other lines of evidence which go towards his point in suggesting that the child is "open" to certain kinds of disorders only until about the age of seven. Such evidence has appeared in relation to studies of early environmental deprivation, diabetes, phenylketonuria, febrile convulsions during childhood, and childhood autism.

With reference to the deprivation literature, the case is least clear. As is well known, there is a large literature on maternal deprivation and institutionalization of children, and there is some disagreement about the severity of disorder which some claim children receive from these treatments. In an earlier review of this literature in 1961, Yarrow notes -- skeptically -- a consensus in the literature that maternal separation before 5 is apt to be most damaging to the child. Later, reviewing the literature in 1964, Yarrow is clearer about a terminal age for the effects of one kind of separation, that associated with hospitalization:

> "In regard to the effects of hospitalization, these studies suggest that the critical period, that is, the developmental period during which children are likely to be most susceptible to damage by hospitalization, extends roughly from seven months to seven years, with the most vulnerable period being seven months to three years..."
>
> (Yarrow, 1964, p. 115)

Figure 11 shows the results of a survey of intelligence test data gathered from some 38 diabetic children, aged 3 to 18 years. A Stanford-Binet test was administered to each diabetic child in the sample and to one nondiabetic sibling of each child, the sibling serving as a control subject matched in everything except age and sex. The figure at the left side shows IQ differences between each pair of diabetic and nondiabetic sibs, plotted over age at onset for the diabetic sib. The figure indicates that diabetic children with onset before five years of age had IQs generally below those of their sibs; the right side of the figure shows that there were 13 such children, with IQs averaging 10 points below those of sibling. Diabetic children with onset after five years of age had IQ scores averaging within one score point of the nondiabetic sibs. This evidence suggests that diabetes produces a decline in intelligence before five years of age, but not after (Ack, Miller, and Weil, 1961).

In the case of another disorder, phenylketonuria, there is data suggesting the same kind of IQ vulnerability in an opposite way -- that is, data to suggest that the IQ scores of afflicted children may often be improved by appropriate treatment up until age five but not thereafter. In a volume on the management of phenylketonuria, Bickel and Grüter (1963) survey 20 case histories of phenylketonuric children treated with a phenylalanine-free diet, and conclude that such treatment may improve the IQ by 10 to 30 points within the first five years, but will produce only negligible improvement after that age. Amount of improvement in IQ seems related to how much before five treatment is begun.

Another abatement of vulnerability occurs in the case of convulsive seizures during childhood. It is not uncommon for young children running a high fever to show febrile convulsions. These are not commonly regarded as serious, and children manifesting such seizures are commonly given mild medication until age 6, which is accepted as the age at which febrile convulsions disappear in children (Carter, 1964).

Finally, mention should be made of what appears to be a critical age in the rare but extremely interesting syndrome of childhood autism. Most psychologists are familiar with Bernard Rimland's excellent recent analysis of the clinical material pertaining to this disorder (Rimland, 1964). Further analysis since that volume was written has pursuaded Rimland that there is a critical age in the evolution of this disorder occurring at 5 1/2 years of age. At age 5 1/2, a great deal of the symptomatology of the autistic child abates. At the same time, there is a turning point in prognosis. If a child develops useful language by 5 1/2, there is a chance he will recover, but if not there is not much chance (Rimland, 1965, 1967).

The abatement of symptomatology in autism at age 5 1/2 is of extreme interest. Here follows a brief quote from a parent's letter to Dr. Rimland:

> "I should add that our boy has been making quite heartening progress in the last few weeks, at least in our estimation. This is particularly true in the areas of speech which are covered in your Questions from about 66 onward. Although we never can predict when we will and will not get a normal response, there are no longer any situations in which we can be sure of getting an abnormal response. His speech has become much more normally communicative, he uses "I" and "yes" with normal frequency, and he has begun to say "thank

> you" and "I'm sorry" with obvious comprehension. He now very commonly looks directly at us when speaking, and he is becoming surprisingly outgoing and affectionate."
> (Rimland, personal communication)

This brief quote mentions the abatement of five of the earmarks of autism in this child, just 5 1/2. To those who are familiar with the autistic syndrome, this letter is a rather dramatic report of signs of recovery in an autistic child.

To sum up the second body of evidence we have been discussing. It appears that Bloom's thesis that the intelligence of the child is stabilized around age 7 is consistent with several lines of evidence. Evidence consistent with the thesis is found in examination of the age-course of a number of pathological phenomena. Each line of evidence says in some way that the child shows mental or neurological vulnerability until the age range from five to seven, after which there is a kind of "hardening" of the child's status. The child is less vulnerable to disorder, or he grows out of certain problems, or -- in the unhappy case of phenylketonuria -- he becomes less open to treatment.

We return now, after an extended tour of the literature on physical growth and the literature on pathology, to our original question. We are concerned with the question of whether the extensive evidence of cognitive changes in the child between five and seven years of age may reflect some change in the child which is independent of schooling, perhaps a precursor to it. We have now to approach that question in another way, by asking if other societies which do not have universal schooling somehow give an impression by their treatment of the child that he is changing in this age range.

It must be recognized that our society makes not one but several acknowledgements of compentence in the child at 6 and 7 years of age. We place him in school. The English common law, the basis of our own common law, assumes that the child is first capable of knowing right from wrong, first capable of being guilty, first legally liable to trial for a crime, at seven years of age. All this as codified in Blackstone's Commentaries in 1769 (and long ago supplanted by the juvenile court system). The Catholic canon law makes similar presumptions about the child and first assumes him capable of knowing right from wrong, capable of confession, eligible for first communion, at age 7.

Of course, the English common law and the Catholic canon law, were once substantially one and the same, and reflected the thinking of an older European society which was decisively not child-centered, which apparently had no adolescent culture and no adolescent society, and which took it for granted that children were grown up by the time they were 7. Phillipe Aries has described the treatment of the child by the society in his book Centuries of childhood:

> "Once he had passed the age of five or seven, the child was immediately absorbed into the world of adults..."
>
> (Aries, p. 329)

> "In the Middle Ages, at the beginning of modern times, and for a long time after that in the lower classes, children were mixed with adults as soon as they were considered capable of doing without their mothers or nannies, not long after a tardy weaning (in other words, at about the age of seven). They immediately went straight into the great community of men, sharing in the work and play of their companions, old and young alike."
>
> (Aries, p. 411)

How do other societies view the child? Several years ago, Anita Rui Olds and I undertook a search through material of the cross-cultural files at Harvard, looking for evidence on this issue. John and Beatrice Whiting were kind enough to furnish us with a list of cultural materials which contained some richness of information about child development and the treatment of children and accordingly, after some free sampling in the files to get an impression of the kinds of information they would be likely to offer, a systematic search was made through the records of 27 cultures to obtain all indications of cultural practices falling under five headings, the headings given in Table 1.

One of our headings was, "A cultural view of the child as reasonable or teachable after this period, in contrast to a mindlessness or lack of trainability before this time." We were motivated to search for such entries because Dr. Beatrice Whiting, in her Six Cultures studies, had found cultures which used the culture word for "mindless" to refer to children before five years of age. Here we were looking for a cultural belief about the susceptibility of the child to training before a certain age.

Our second category was "Demands that the child accept moral responsibility at a later age, in contrast to a laissez-faire attitude before." Some cultures, in effect, lay down the law to the child when he is six or seven, indicate to him that he has been getting away with things before but now he is expected to "shape up," follow the rules, and so forth.

Our third category was titled "Initiation ceremonies during this period."

Our fourth category was titled "Some indirect assumption of adulthood such as the assumption of adult work, a practice of separating male children from the mother or female sibs, new demands for modesty practices, etc." It seems to say something for Sigmond Freud, Malinowski to the contrary notwithstanding, that this search category produced our richest yield with some 93% of the sample of cultures having practices that fell under this heading. It is apparently quite common to separate the sexes in this age range, with boys sent to work with the men and the girls sent to work with the women. (If the culture is a hunting culture, and the men must travel long distances, the boys will not go with them until they are somewhat older.) The children are given loincloths if they have not had them before, and so forth. By and large, all of the entries in this category have some plausible connection with the assumption of sex-role identity, or an acknowledgment of the child's sexuality, at around this time. (These acknowledgments, in turn, may underlie widespread practices of extrusion of the child from the household, or institutionalized brother-sister avoidance, customs of a number of societies with regard to the child from eight to ten (Cohen, 1964).)

Our fifth, and final category was titled "Any religious, mythological, or theoretical view which implies that the child becomes more human, less foreign, etc., during this period." This category found only 22% of our sample. It was included because in our preliminary search we came across a single entry -- which I now believe must be something of an anthropological whopper -- to the effect that one culture will kill a child if he becomes seriously ill before four or five on the assumption that he is a snake or other animal masquerading in human form, but which will treat him if he falls ill after five, accepting him as a sick human.

These cross-cultural data seem interesting, and therefore they have been presented, but there are serious weaknesses in this kind of cross-cultural information. Assuming there are changes between five and seven, the data describe the ways in which human societies react to those changes, but the data are not themselves an independent source of evidence that the changes exist.

First, the cross-cultural files are ambiguous. They were made up by imposing a uniform, elaborate index on a body of ethnographic reports. The ethnographic materials were almost never collected with the index in mind and thus, in many cases, there are missing index entries, or the index entries are skimpy and casual quotes lifted from the running text of a book. One has some difficulty understanding the ethnographer's meaning, or one may have difficulty deciding whether quoted material represents a studied conclusion or a casual and guessy remark by the writer. Hence, the problem of reliably interpreting the file entries is formidable.

A second and overridingly serious problem for our kind of use of the files lies in the issue of age-determinations. Non-literate cultures almost never know how old a child is, and statements about age in ethnographic reports always represent approximations or guesses. Unhappily, one can be fairly confident of a bias in ages arrived at in this way; almost certainly, an anthropologist would be tempted to guess at a child's age in part through his own, Western expectations about what should normally be expected of children at various ages.

In short, these cross-cultural data may color our suppositions about this age period, without lending weight to them. Taken at face value, the data just presented are not discouraging to one who would like to believe that there is some universal recognition of change in the child in this age range. However, they are not forcing.

We turn, finally, to our third category of evidence. Here we are concerned with evidence which might help us to decide whether specific behavior changes found in the child between five and seven years reflect some intrinsic developmental process independent of his entrance into school, or whether instead they primarily reflect an influence of schooling upon him. Our test is whether these changes emerge in populations of children who are not placed in school in this age range.

A number of studies have provided evidence that various cognitive changes reported in the conventional research literature can be demonstrated in unschooled populations of children. Price-Williams (1961), working among the Tiv in Nigeria, studied Piagetian conservation of continuous and discontinuous quantities and found the Tiv children about one-half year behind reported age achievements of European children. In another study among the Tiv (Price-Williams, 1962), he studied the ability of children to cross-classify objects, with, again, data comparable to those of European children. Similarly, Sigel and Mermelstein (1965), administering Piagetian conservation tasks to unschooled American children in Prince Edward County, has found that the children developed conservation at the expected ages and Goodnow (Goodnow, 1962; Goodnow & Bethon, 1966), working with unschooled children in Hongkong, has reported that lack of schooling does not upset the conservation of weight, volume, or surface, but does upset a task of combinatorial reasoning.

One may assume from these data that some cognitive changes may develop without schooling. However, there is also some evidence showing cross-cultural differences. Suchman (1966) has reported that a shift from "color-dominance" to "form-dominance," repeatedly found to occur at age 6 in Western children, was not manifest by age 17 in an African sample. Suppes (1966) has found that a sensitivity to rotation of forms, which peaks in American school children at 6 years of age, does not develop in school children in Ghana at all, and he links the American data to the influence of reading training in the first grade. Finally, though most of the cross-cultural studies of Piagetian conservation tasks have found them unaffected by lack of schooling, some data in Bruner, Olver and Greenfield's (1966) volume does suggest that they are influenced by schooling.

The total literature testing unschooled groups of children is still small , but within the literature we have there are indications that some of the research results reporting age shifts between five and seven are confirmed in children who have not been exposed to school.

We move towards a close. We have considered several bodies of data, testing whether age changes in the child not attributable to schooling occur between five and seven years of age: evidence of deflections in physical growth, of changes in vulnerability to disorder, of changes in the practices or theories of various cultures, evidence drawn from cross-cultural studies testing the Western reports of change in the child. Despite the weaknesses of many of the sources, despite the missing logical links in the research material, my own inclination is to accept these data as indicating that there is a substrate process of change in the child. The many research reports which show deflections in children are not telling us about the impact of schooling -- not wholly, at any rate. To some extent, they are telling us about developmental changes in the child.

What do these developmental changes mean psychologically. Educationally? Over the past decades, there has arisen a distant harmony among educational, psychological, and psychiatric writings, and by now a diverse group of individuals are asserting, in diverse ways, that there is some significant alteration in the mental functioning of the child during the age range from five to seven. The child is asserted, normatively, to have "readiness" for reading training as the schools give it and he is occasionally said to have lost readiness for certain kinds of preschool learning envisaged in the methods of Montessori. The child is asserted, normatively, to have reached the terminus of a juvenile psychosexual period and, between the ages of five and seven to develop a superego, to inhibit juvenile psychosexual period and, between the ages of five and seven to develop a superego, to inhibit juvenile sexuality, and to repress -- develop an amnesia for -- the preceding events of childhood. Finally, the several contemporary traditions of inquiry into the child's learning and cognitive processes have each independently asserted -- each in its own terminology and each on its own evidence -- that whatever each system considers to be the essence of symbolic or abstract thought processes is emergent in the child from five to seven. For American S-R theorists, this is the time when mediation begins; for the Russians, this is the time when the second signal system is internalized to become the human organ of planning and reasoning; for Piaget this is the time when concrete operations emerge.

The separate theorists do not consider or explain one another's findings. None encompasses a large literature of reports of age changes which seem to fall outside any of the theoretical camps. Yet one can clearly foresee that the theories and the data, all bearing on the same range, seem dimly to delineate a uniform picture of the developmental substrate.

1. They suggest the inhibition of a more juvenile system of cognitive processes in this age range, with the superimposition of a more mature system of cognitive processes.

2. They suggest the existence in the older child and the adult of at least two cognitive systems, one with a juvenile logic generally characterized by the studies of the child before five, the other with an adult logic generally and vaguely described as conceptual thought, and delineated by the studies of the child after seven.

3. They suggest that the juvenile logic has been roughly described by associationism and learning theory, and that the precise qualities necessary for conceptual thought are delineated in the transitions from five to seven. At the moment these transitions, which need further exploring, seem to depend on a limited number of new information-processing vectors -- greater speed of reaction motorically and, it seems, internally; an increase of temporal coordination of information; and perceptual changes in near-receptor, distance-receptor dominance, in intersensory coordination, and in orienting and habituation thresholds.

4. In the older child and the adult, the juvenile logic and the adult-logic coexist characteristically in a temporally stacked system -- the juvenile logic relatively fast acting, and somehow requiring

inhibition if the adult logic is to control behavior. Thus, the characteristics of impulsive thought may be juvenile, the characteristics of reflective though adult.

5. This temporally stacked arrangement seems delicate and patterns of short- or long-term stress may produce regression to -- that is, disinhibition of -- the more juvenile logic. Thus, we find the repeated reports of psychopathological thought disorders described as regressive. Thus, we find Skemp (1961) arguing that children often have problems in school mathematics not because they do not have the requisite intellectual structures, but because stress disrupts their ability to apply them. Thus, we find that in the aged adult, at the time of what society calls "second childhood," there is literally a reversal of some of the 5-7 transitions and behavior patterns characteristic of the pre-5 child reemerge, (e.g., Levinson and Reese, 1967).

6. Parenthetically, it has seemed to me that behavior therapy may have more wisdom than it admits to. Behavior therapy, like psychoanalysis, may have found a way to reach into and change the juvenile system of which juvenile logic is a part. It contrives to introduce repetition, which younger children enjoy but which older children generally find boring. It contrives to manage and focus the attention of the child, a precaution which we take for granted in the younger child but which is much relaxed for the older child. It uses tangible and sensuous rewards, necessary for younger children but not for older, normatively achievement-motivated children. The design features of behavior therapy which engage the juvenile logic in learning, rather than the reinforcement theory which applies to that learning, may be the real art of behavior therapy.

These comments about the implications of the 5-7 material for our understanding of learning and cognitive processes must not obscure the breadth of the transition. It is necessary to take that breadth into account. Contemporaneous to the 5-7 changes in learning, there are significant changes reported in the physiological, perceptual, and emotional literature and the chances seem good that these are linked to the cognitive changes not by logic (some common subsumption under a theoretical or functional principle, like decentration, concrete operations, or mediation) but by bio-logic, the bio-logic of Hughlings Jackson. Nature, which does not respect the chapter headings of Psychology, may produce a genotypic maturational change which manifests itself in a broad spectrum of phenotypic, conceptually dissimilar, behavioral outcroppings. That maturational change may be understood by efforts to trace the outcroppings towards some common source. For the first time, today, there may be enough breadth and depth to the neurophsiological and behavioral literature to make this a real possibility (e.g., Milner, 1967).

I believe that it is only by analysis on this scale that we will comprehend the changes in children's learning in this age range. Within the learning literature, the large literatures we have collected on the transposition phenomenon, on mediational versus attentional explanations of changes in learning, on training of conservation, all seem to have raised more issues than they settle. Perhaps the learning literature is too confined, too restricted by the limited number of things that one can see and do in learning experiments, to probe its way towards an adequate explanation of its own findings. Looking at the larger field of data, however, one can envisage the possibility of an interesting and worthwhile theoretical scheme -- something like a highly refined and detailed and physiologically rationalized form of Heinz Werner's Comparative Psychology of Mental Development -- if the various phenotypic phenomena are traced towards their intersection by an imaginable elaboration and exploration of information we now have.

Psychology's ancient problem has been to define the nature of conceptual thought, Education's to foster it. If, as the rumors have it, that level of thought emerges in the child from five to seven, then it seems that in some worthwhile sense we may now have data which, so to speak, surrounds those problems and which offers routes towards their solution.

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FIGURES TO ACCOMPANY "CHANGES IN LEARNING PROCESSES IN THE LATE PRESCHOOL YEARS"

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Table 1

Crosscultural Incidence of Acknowledged Change in the Child Between Four and Eight Years of Age[1]

Scoring Category	Percent Incidence
a) A cultural view of the child as reasonable or teachable after this period, in contrast to a mindlessness or lack of trainability before this time.	37%
b) Demands that the child accept moral responsibility at a later age, in contrast to a laissez-faire attitude before.	33%
c) Initiation ceremonies during this period.	26%
d) Some indirect assumption of adulthood, such as the assumption of adult work, a practice of separating male children from the mother or female sibs, new demands for modesty practices, etc.	93%
e) Any religious, mythological, or theoretical view which implies that the child becomes more human, less foreign, etc., during this period.	22%

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[1] Based on ratings of the records of 27 cultures in the Harvard crosscultural files (White and Rui, 1964, unpublished).

NOTE: The following 31-page section, "Some General Outlines of the Matrix of Developmental Changes Between Five and Seven Years," by Sheldon H. White, is copyrighted and not available for reproduction at this time. See Bulletin of the Orton Society, 1970, 20, 41-57.

COGNITIVE CHANGES DURING THE LATE PRE-SCHOOL YEARS:
NON-WESTERN EVIDENCE FOR UNIVERSALITY

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It is virtually universal in Western societies for the social and educational status of a child to be significantly redefined sometime during the fifth, sixth or seventh years of life. Evidence can be marshalled from a variety of sources that this universality reflects more than cultural diffusion of an arbitrary social organization. First, most psychological theorists who have attempted to encompass the scope of human development have located within this age span beginnings of new adultlike behaviors. Second, psychological research has demonstrated a large and curiously heterogeneous collection of qualitative changes in the behavior of Western children around the sixth year, changes in learning, language, emotion, perception, and intellectual structure. Third, the physiological and anthropometric literature point up a variety of growth phenomena during these years. Lastly, there is cross-cultural work to suggest both that non-Western children may undergo similar changes, and also that most non-Western societies show some implicit recognition of new characteristics emerging at this age.

Piaget and his associates, in their broad theoretical view of intellectual development, place special emphasis on the beginnings of "operational" thought in the sixth or seventh year (e.g., Inhelder & Piaget, 1964). The progressive ordering of thoughts and operations into coherent, equilibrated systems is seen to lay a logical foundation for the stable understanding of the world which is culminated several years later. The same age is the focus of a theoretical orientation in the Soviet Union which dates back to Pavlov: around the sixth year, the control of behavior shifts from the simpler, classically conditioned mechanisms, to a higher level. For Pavlov, this was the appearance of the "second signal system." Building on this work, Vygotsky (1962) attributed the onset of adult-like conceptual thought to the union of language with thought. More recently, Luria (1961) has demonstrated the pervasive implications of this more mature relationship for the control of behavior. The American "mediation theorists" point to a similar process in the sixth year, as language plays an increasing role in mediating conceptual learning (Kuenne, 1946; Kendler & Kendler, 1962; Kendler, 1963). In the realm of psychodynamic phenomena, Freud has argued for the onset of significant inhibitory mechanisms at this time. Following the resolution of the Oedipal conflict, sexual identity is firmly established and the normal child begins to form an adult-like superego. The onset of the latency period is accompanied by infantile amnesia. The concordance of these theories, which arose largely independent from each other, is impressive. For each theorist, in his own language and from his own data, the period around five to seven years of age is seen as the beginning of a dramatically more mature organization of the mind.

White (1965, 1966a, 1966b, 1968, 1970) has presented summaries of many of the changes shown to occur during this age range in children's learning, language, emotion, perception, growth, and intellectual structure. Many of these experimental results flow directly from the theoretical works mentioned earlier, but a significant number of them appear quite unexpectedly. Most germane to the present issue of nonsocial causes is White's review of the physiological and anthropometric research on these years (White, 1968). He cites a variety of sources which document a "juvenile growth spurt," or "midgrowth spurt," which may be most reliably seen in measures of width (Tanner, 1947). Neural tissues, of particular interest to psychologists, are said by Scannon (1930 to have reached 90% of their adult mass by age six. In a study of neural functioning, Dustman and Beck (1966) have shown that the visually evoked potentials from cortical areas peak in amplitude around the sixth year. There is also some evidence for change in endocrine function at this time (see Tanner, 1955a, 1955b) but as in other areas, the specific mechanisms have not been located. Thus, it appears that the years from five to seven are a significant period in bodily, neural, and endocrine development, but our knowledge of what actually is occurring as regards brain function is quite limited.

A second line of evidence reinforces the suggestion that this age range is of particular physiological significance. As reviewed by White (1968), environmental deprivation and a variety of medical disorders such as diabetes are most debilitating to intellectual functioning when encountered in the first five years of life. Febrile convulsions, phenylketonuria, and childhood autism also show changes in their effects, openness to treatment, and/or prognosis around the age of six years. After this age, there seems to be some kind of "closing of the system," as the brain becomes less vulnerable to permanent damage by some pathologies and less adaptable to others. It can be noted in this context that Bloom (1964), studying intercorrelations of longitudinally collected IQ scores, reaches a similar conclusion concerning the normal stabilization of intelligence.

If there are unique changes in physical and physiological growth during the years five and seven, and if the social and psychological changes which appear to accompany them in Western children are not entirely the product of changes in their social and educational environment, we should be able to find anthropological evidence of some similar changes in the children of non-Western societies. Unfortunately, little work has been directed to this point, but two lines of evidence are available. First, there is a suggestion that other societies place new educational, legal and moral demands on the six-year-old as do Western education, common law, and canon law. White and Rui (1964) searched the ethnographic reports in the Human Relations Area Files for evidence that other societies give some implicit recognition to changes in the child at this age. They looked for indications that the child was viewed after this age as reasonable or teachable, as morally responsible, as able to take on adult work, as needing more strict supervision in the areas of sexuality and modesty, or as worthy of a new role in the culture's religious or mythological scheme for man. As the authors acknowledge, the results are open to question because of ambiguities in the Files concerning specific behaviors, lack of verified ages of the children, and possible bias by the Western ethnographers. Nevertheless, they do suggest that most societies appear to be coping with these problems at this age. Most dramatic was the 93% incidence of societies having "some indirect assumption of adulthood such as the assumption of adult work, the practice of separating male children from the mother or female sibs, new demands for modesty practice, etc." (White 1968, p. 17).

The second cross-cultural approach, which the present study will pursue in some detail, is to observe the fate of psychological tests developed for Western children when these tests are administered to non-Western children with little or no schooling. Most such attempts, designed toward other ends, have focused on older age groups and therefore cannot speak to the present issue. The work of Serpell (1969a), Suchman (1966b), and Suppes (1966) are notable exceptions for they directly address the question of whether a particular Western "five to seven" phenomenon occurs in non-Western children. In these cases--concerning the relative importance of color and form in stimulus grouping, and children's sensitivity to rotation of geometric figures--the results were generally negative.

The larger set of studies attempting to replicate the Piagetian work on operational thought is also relevant since, as mentioned earlier, this ability is said to emerge around six or seven years of age. The normative Genevan data on attainment of conservation of weight, number, volume, etc. (Vinh-Bang & Inhelder, 1963) has been essentially duplicated for Western school children in Canada, the United States, Great Britain, and Scandinavia (Pinard, 1960; Elkind, 1961; Lovell & Ogilvie, 1961; and Smedslund, 1961). Early work on populations which were only "partially schooled" in Aden (Hyde, 1959), Hong Kong (Goodnow, 1962; Goodnow & Bethon, 1966), and the United States (Sigel & Mermelstein, 1965) tended to support the idea that not only the sequence but also the timing of attainment of concrete operations are independent of Western schooling. However, Price-Williams (1961, 1969), de Lemos (1966), Greenfield (1966), Keir (1966), and Heron and Simonsson(1969)have shown attainment to be delayed from one-half to four or more years in populations from Nigeria, Mexico, Australia, Senegal, Tristan da Cuna, and Zambia. From these studies emerge several clues as to the role of educational and cultural factors.

One effect of Western schooling can be to focus the young child's attention on the way things look. American children (Bruner, 1966b) and schooled Wolof children, both urban and bush (Greenfield, 1966), rely heavily on perceptual justifications of their responses to the conservation of volume task. If the vessels are screened from their view while the liquid is poured, young children in transition to conservation are protected from the misleading visual cues, and thus are more likely to give a correct answer. In contrast, unschooled Wolof children, both conserving and non-conserving, are not so dependent on perceptual reasons, and screening does little to improve their performance. Their failures, rather, stem from attributing "action-magic" to the authoritative experimenter: allowing them to perform the pouring transformation themselves increases their conserving responses to the level of their schooled village-mates and Western children.

The results of Heron and Simonsson (1969) and Goodnow (1962), however, demonstrate that "schooling" can have, or not have, a variety of effects. In the former study, fully a third of Zambian seventh graders failed a non-verbal test of conservation of substance. In the latter, a poor curriculum, particularly in science, was associated with a decline in conserving behavior during the early teens. De Lacey (1970), Heron and Simonsson (1969), and de Lemos (1966), among others, have pointed out the crucial role of what happens outside school and the general cultural ambiance. The work of Price-Williams (1969) has focused on the specifics of non-school experience. Following up his own suggestion (1961) that active manipulation might be a factor in the minimal lag in conserving by unschooled Tiv children, he studied the children of potters and of non-potters in two Mexican villages. In both cases he found that the potters' children attained conservation at a rate similar to the Swiss norms, whereas the other children lagged by a year and a half. In the cases of those children who had the most extensive experience working with clay, their advantage generalized to include conservation of number, liquid, weight, and volume. Sigel and Mermelstein (1965) postulate similar factors behind the sex differences in their data, and Kier (1966) points to the absence of such activity in explaining the delayed conservation by Tristan da Cuna children.

Variations in performance on the Geneval tests, then, are probably best viewed as a complex result of implicit social and intellectual patterns, explicit training of intellectual attitudes and strategies, and specific long-term experiences with relevant objects. All of these affect the formation and integration of cognitive structures, and their utilization in a particular situation.

Regardless of the ultimate validity of this view, however, there remains the question of whether some internal change around the age of six produces the potential to understand the world in certain ways, which potential may or may not be brought to fruition in all domains. To this point, we should note that statements concerning delayed attainment of conservation focus on the age at which half the subjects succeed. But the changes with age in group means are not linear. In every study, there is a steep rise in attainment beginning around the seventh year. Greenfield (1966) provides the cleanest case in her unschooled bush children: 25% conserving at "six to seven" years, 45% at "eight to nine", and 50% at "eleven to thirteen." (Heron & Simonsson's (1969) and de Lemos' (1966) data are more dramatic but the possibility of a "pull-up" effect by early schooling cannot be eliminated, even in view of the limited final effects.) That a change as fundamental as the onset of operational thought should begin so dramatically at a similar age in several diverse cultures is impressive.

In sum, there is evidence of many sorts, from many sources, suggesting that between the fifth and seventh years of life all normal children undergo a relatively subtle but pervasive change in their physical and mental growth, and that these changes will occur naturally, without any specific and direct prodding. The hypothesis is by no means proven, however, and as one progresses from Geneva to Dakar, and from skeletal structures to cognitive structures, the evidence grows weaker. It was the goal of the present project to sample the variety of tasks which have been reported to show these changes in Western children and to administer them to children of a society relatively untouched by the culture in which they were developed. It was hoped that the results would shed some light on which aspects of the "five to seven shift" can be thought to be relatively universal. Such delineation could point toward underlying processes and how these processes might be affected by the social context in which they operate.

THE STUDY

Description of the Populations

Two samples, one urban and one rural, were studied in the Central African country of Zambia. Zambia is sparsely populated (3.8 million Africans and 100 thousand Europeans and Asians in 288 thousand square miles), with the more skilled and educated residents concentrated around the copper industry in the north and the government in Lusaka. Other industries and commerce are growing rapidly, especially since independence from Britain was won in 1964, but life for the vast majority of citizens remains rural, traditional and at a low economic level.

The urban sample was drawn from Matero, a residential area of Lusaka made up of one-story, two-family structures with two or three small rooms per family. Sanitary facilities are separate from the house and running water is usually obtained from one of several communal taps. An attempt was made to test all the children (plus some teenagers and adults) in a three block area near a community medical clinic. A recent survey of Matero by the medical team (Leeson & Frankenberg, 1968) suggested that approximately 227 children between the ages of three and eleven lived in this segment. (Because of high turnover, no exact figure is possible). The average child in the current sample lived with his parents and one other aeult (usually male), and four other children. A total of 28 tribes were represented, six of them (Konde, Bemba, Cewa, Nsenga, Mambuse, and Ngoni) contributing 50% of the sample. Ninety percent of the marriages were inter-tribal. The fathers had an average of five years of education, and the mothers two. Occupations of the fathers ranged from unemployed (rare) to driver or clerk with monthly incomes of up to $100. Most households were Protestant with some Catholic, Islamic, and Pagan. Virtually all the men and about half the women claimed to be literate in a Bantu language. Most of the adults were born in rural areas, as were over half the children studied. Two thirds of the homes had a radio. A more detailed description of a similar but somewhat more prosperous suburb has been given by Munro (1968).

A growing body of literature (Cabak & Najdanvic, 1965; Stoch & Smythe, 1967; Scrinshaw, 1968) suggests that not only gross physical disabilities but also previously overlooked subtleties of nutritional deficiency in the early years of life can substantially affect intellectual ability. With this in mind, we note that neither the overall health standards nor the nutritional level of the Matero population is high. Data from the medical survey indicated that over half the children in the present sample had lost a sibling. (Since there are many siblings this does not imply a 50% death rate.) Over a quarter of the families have no special cupboard in which to keep food. Cooking is often done over an open fire and the water is of questionable quality. The children have few clothes, and on the chilly winter mornings they are reluctant to leave the hearth. No overt malnutrition was observed, but it has been estimated by Fisher (1968) that "between 70% and 80% of the primary school children (in urban areas) ... suffer from some form of malnutrition." Twenty percent of the children admitted to the Lusaka Central Hospital for measles die mainly because of complications due to malnutrition (Savage, 1968). Major factors in the poor nutrition are substitution of soda and sweets for the traditional cornmeal (nshima) and relish; intestinal parasites; and the low priority of children in the distribution of food.

School attendance is normal for the urban children, most of them beginning around age seven. Since the present data were collected during the short school vacation, attendance did not interfere with sampling. Table 1 shows the distribution of grades by age for the present sample and it is evident that the relationship, though strong, is not as uniform at upper ages as in Western cultures.

(Insert Table 1 about here)

Three hundred miles from Lusaka on the Great East Road lies the town of Katete, consisting of a gas station, two or three trader's shops, a small market, a Hindu Temple (serving the Indian traders), and a few other structures. St. Francis Hospital, part of the Episcopal mission system, is several miles to the west, and the small British staff are the only Europeans seen regularly in the area. Sixty miles further east is Chipata (Fort Jameson), the largest town in the Eastern Province. A dirt road leading south from Katete soon takes one to the district boma where there is a post office and several governmental offices, including that of the District Secretary. A small school, two churches, and a number of houses complete the settlement.

The boma road, followed some 10 miles south, leads one by the village of Chimbelekiro, from which about half the rural sample is drawn. According to a 1963 census, there were 194 inhabitants, of which it was estimated about 25 were children between three and eleven years of age.

The village is said to have grown since then. Several miles further a dirt trail, barely passable by Land Rover, leads to the other sampled village, Kazule. Three hundred ninety-nine people were recorded as living there in 1963, of which approximately 50 would be the right age for this study. In both villages round mud huts with unthatched straw roofs cluster around a clearing in the light woods typical of the Eastern Plateau. They are laid out with concern toward family units but with no apparent geometric organization.

The people of the villages are Cewa, related to the Nyanja and Nsenga peoples. Before colonization, the Eastern Province Acewa had migrated north from what is now Mozambique, only to be dominated by the more aggressive Ngoni tribe. It is estimated that they settled in the Eastern Province as the colonials entered with their Pax Britannica (Tew, 1950). The Acewa are largely agricultural, corn and peanuts (maize and groundnuts) being the major crops. Cattle are seen in the villages but are kept largely as a sign of wealth and for payment of bride prices--they are "blue chip stocks." Other domestic animals, such as pigs and goats, are an innovation within the last generation or so (Bruwer, 1955).

A few short ethnographic reports exist on Cewa groups. Social organization has traditionally been matrilineal and matrilocal. The village was a conjoint family group, with the huts of those descended from a "breast" of the family clustered around the hut of the maternal grandparents. Religious and political life was largely organized around animistic secret societies, called vinyau (Hodgson, 1933). A system of guardianship decreed that the child was the judicial responsibility of the maternal uncle, even though day-to-day life was the concern of the entire community in most cases (Bruwer, 1949, 1955).

The traditional Cewa, according to Bruwer (1948, 1949), was born in his mother's hut and accepted into the tribe at one month of age. He continued to sleep in her hut until weaned, around three or four years, unless he became "clever" earlier. Leaving the parent's hut at the end of this first stage, he went to live with his maternal grandparents. They were the story-tellers, the bearers of traditional wisdom. After a few years, the child was teased for living with grandparents and around seven, he moved to a hut with unmarried peers. The youths were generally free from parental influence, although the girls helped their mothers with chores and the boys tended cattle. This stage ended with the initiation rites at puberty. For a boy, a brief ceremony after the first erotic dream declared him a man. Becoming a woman was more complicated: ceremonies started with the first menses and lasted through the first pregnancy. Married adults went to live with the wife's relatives and the cycle started anew. Writing in 1949, Bruwer (1949, p. 198) noted that "much of these things have been dropped today, as a result of Christianity and civilized influence, but the four main periods of life are still eminently clear."

Discussions with the headman and other adults in the villages of the present study revealed that while much of the traditional remains, change has accelerated. Most obviously, the matrilineal organization has been abruptly replaced by patrilineage and patrilocality. The Europeans' social system, like their political and economic ones, are rapidly becoming prestigious and dominant. The Cewa chiefs simply decided to alter their social structure and join with those tribes traditionally patrilineal as an effort toward "One Zambia, One Nation." The village headmen were preceded by their maternal uncles, but will be succeeded by their sons; patrilocal residences are growing more common. Other changes are apparent too. New houses built in Chimbelekiro will follow a geometric arrangement. About three-quarters of the village inhabitants are at least nominally Christian, either Roman Catholic or African Reformed. Polygamy is still permitted, but it is said to be rare. In spite of these changes the village remains quite isolated, with no women and only a few men having travelled as far as Katete and its boma.

The pattern of growing up as recounted to the author by village adults appears similar to Bruwer's description. The first stage ends around three or four years when the child moves to sleep at his grandparents' hut. The second stage ends at five or six years when the young males start taking part in the care of cattle and the young girls start helping with the preparation of cornmeal and with other chores. The major criteria for this transition seemed to be size: just under 4 feet was the dividing line. When a child is "old enough to go to bed with someone," he is old enough to work in the garden and get married in a few years. This transition occurs around thirteen to fifteen years. It is unfortunate that the earlier ethnographic reports were not available before the present study began, and no specific inquiry was made about moving from the grandparents' hut to an unmarried peers' hut at age five or six. Such a change was not mentioned during several lengthy discussions of Cewa life, and no particular evidence of the change was seen in observing daily routines. But in the absence of direct evidence to the contrary, we cannot rule out the possibility that this custom remains.

The content of childhood, in any event, seems to lack the discontinuity of sleeping arrangements. The Acewa have no formal category of "childhood" as a separate state of life. There is one village life in which all participate according to their ability. Roles and activities differ as a function of sex and physical and emotional maturity, but the process of growing up is a more continuous one than in Western cultures. Obedience and cooperation are the child's most important duties, violations of which are treated seriously. Deviations from the known and traditional are discouraged. Much of the child's play is in imitation of adult activities, often blending with the chores assigned them. Imitation, in fact, seems to be the major process of learning. The Cewa way is the context of life, and as the child matures he absorbs the behavior expected of him. While the stages of childhood described earlier may dictate some physical aspects of a child's life, there appears to be few abrupt changes in daily activities, no sudden onset of didactic instruction, no formal entry into a new way of life. Bruner (1966a) offers a cogent discussion of this aspect of enculturation among non-industrial societies and the implications for the course of cognitive growth. For the present study, we should note the continuity of development and the absence of redefinition of the child and his life during the middle of the first decade.

Literacy and education are valued by most villagers as part of Zambia's future (they made a generous contribution in the national drive for funds to start the University), but do not touch their daily lives. Government schools have been established in the area for several years, but only 10 children from Chimbelekiro and about 20 from Kazule attend classes. These are mostly later-born boys who could be released from family chores and were old enough to walk several hours to school every day. They were selected by the headman with the parents' consent.

In summary, Western values and ideas have reached the rural villages in this sample, as evidenced in the social and religious reorganization, and the recent entry of formal education. But so far, these changes seem largely structural trappings. Isolated from all but a few neighboring villages, the Cewa have assimilated trousers and patrilinearity but accommodation has been minimal: the content of daily life remains traditional in orientation, value, and activity.

Nutrition in the villages is at least equal to that in the Matero sample. After weaning (which can be as late as three years if no siblings follow), the major daily meal is nshima (a corn mush) and a relish of vegetables or occasionally meat. A second meal may be similar but is more likely to be peanuts. The absence of unsanitary, diluted bottle feeding in infancy, and of artificial sweets in childhood, and the presence of some high-protein foods in the normal diet all contribute to the relatively high nutritional level of the children in the rural sample. However, parasites and the often limited supply of food can be seen to interfere with health and development. In one of the few quantitative studies of nutrition in Zambia, Thompson (1954) estimated that the caloric intake of the women and children in villages averaged around 50% or 60% of daily requirements. A missionary physician who knew the Acewa (but not the specific villages in the present study) estimated that their nutrition was above this average.

Sampling and Data Collection

A trained local assistant administered the tests in the local language. The author was present at all times, handled some of the testing materials, and engaged in friendly, though limited, conversation. The testing was carried out in the rear cabin of a specially adapted Land Rover. This mobile laboratory contained a small table, cabinet, and two benches capable of seating four people. Curtains were used on the cabin windows to prevent future subjects from examining the stimulus materials and from annoying the current subject.

Introduction to the Matero neighborhood was obtained through the community medical clinic, and although the daily testing activities proved quite a novelty, no animosity or fear was encountered. The Land Rover was parked at one of several locations in the sampled area, and the children who spontaneously gathered were tested. At the end of testing, each subject was given an orange. Only rarely (for example, on a chilly morning) was it necessary to seek out subjects. Virtually all children on the list extracted from the survey data were accounted for as either tested or having moved. A few children refused to be tested, mostly three- and four-year-olds. Altogether, 176 children from three to eleven years were tested, comprising nearly 80% of the presumed target population of 227.

Testing procedures for the rural sample were similar. A local woman with several years of education was trained as an assistant. Only minor changes in the instructions were necessary to replace the few words familiar to the urban children but not the rural. (Chi-Nyanja and Chi-

Cewa are nearly identical for the present purposes.) Testing was done in the mobile laboratory parked in the village. An attempt was made to test all children not in school between the ages of four and ten. This attempt was largely successful for the males, but due to the press of time, a number of females were not tested.

Tables 2 and 3 show the number, age, and sex of subjects in the two samples. Because of the separation of the tasks into two batteries, the incomplete testing of some subjects (mainly teenagers), and occasional unscorable data, the ns vary from task to task and are reported with each set of results.

(Insert Tables 2 and 3 about here)

Estimation and Validation of Ages

The ages of the urban children were obtained from several sources. The survey by the medical clinic contained mothers' reports of birth dates for nearly three-quarters of the present sample. These were checked at the time of testing by self-report and comparison with peers. When there was doubt about the age, inquiry with the mother and/or peers usually resulted in an acceptable estimate.

For the rural children, a combination of procedures was used to estimate ages. First, each subject was paired with those near him in age, in order to obtain rankings of relative age from the children. Substantial disagreement over any pair was interpreted to mean that the individuals concerned were within a year of each other. The final ranked list, constructed and amended throughout the study, was checked with several adults in the community. They agreed with all the unanimous rankings and were able to straighten out all but a half-dozen of the confusions. It was more difficult to pin down absolute ages. Stated ages, available for about half the children, were rarely credible. In each village, however, at least one child could be identified as having been born just before the rains of Independence Year--October-November, 1964. These children provided an anchor point for the low end of the rankings. Puberty was used as an approximate anchor at the upper ages of interest. Between these points, ages were assigned with regard to the natural groupings in the list, adults' advice on who was born "rains apart," and the author's judgment.

Two physical growth measures were taken on both urban and rural children before administering the psychological tests in an attempt to validate the procedures used for estimating ages in the rural sample. If the rural ages are accurate, goes the logic, they should show the same relationship to the physical growth measures as do the more reliable urban ages.

The first measure was to note the presence or absence of adult dentition, particularly the central mandibular incisors which have been shown in several Western populations to erupt during the sixth or seventh year (Vaughan, 1964; Carlos & G. Nelsohn, 1965; Clements, Davies-Thomas, & Prichett, 1953; Logan & Komfeld, 1933). It is generally assumed that "considerable individual variations in the timing of eruption" can be caused by "geographical location, social conditions, race, and sex" (Boyle, 1965, p. 31), but direct evidence on the role of genetic and environmental factors is scarce.

Garn, Louis, and Kerewsky (1965, p. 228) refer to "large racial differences in tooth eruption timing, differences in excess of 10%, when Chinese, Whites, Negroes, Amerinds, Asiatic Indians and Eskimos are all compared." Dental information on Bantu peoples is virtually nonexistent, but it has been demonstrated in some other African samples that the eruption of permanent molars is generally similar in timing to Western samples (Hiernaux, 1970). There is a tendency in some African groups for the second molars to appear earlier than in Caucasoids (Suk, 1919; Carothers, 1947) which Chagula (1960) has related to the precocious skeletal development at birth of some African infants. Hiernaux (1970), however, implies that no mean differences greater than one year between African and Western samples have been adequately demonstrated. This would agree with the estimate of Garn, et al. (1965). In any event, there is no reason to expect on genetic grounds significant differences between the rural and more heterogeneous urban samples of the present study. In the absence of more appropriate information, we can also expect an average age at eruption within one year of the Western norms.

Most of the work on the effects of malnutrition on growth has used somatic measures largely unrelated to the eruption of permanent teeth (Filipson, 1968). The data of Garn et al. (1965), using the well-fed Fels longitudinal population, provide some evidence for a relationship between caloric surplus and advanced dental development, but even there the genetic factor remains dominant. They conclude that "probably because tooth formation has such a high genetic component in man, nutritional factors are easily missed except en masse and in major nutritional extremes" (p. 240).

As a second growth measure, each child was asked to touch his right ear (the auditory meatus) with his left hand, reaching over the head and keeping the neck straight. This is not unually possible until around the sixth year and, interestingly enough, was the criterion for entry into school during colonial times in Zambia.

Figures 1 and 2 show the percentage of children at each age in each sample attaining these criteria.[1] The curves for the two populations, though not identical, offer substantial support for the ages assigned to the rural children. The dental data are consistent with Western norms. The greatest sample differences (not significant) are among the seven- and 8-year-olds, and it will be seen later that their data are occasionally puzzling. No differentiation is possible after nine years, but exact ages are of less importance there for the current thesis.

(Insert Figures 1 and 2 about here)

The Test Batteries

Fourteen tasks were developed and pretested in suburban Boston, Massachusetts. They were chosen from those phenomena showing change during the fifth through seventh years which held promise for relatively simple cross-cultural use. Adapting the tasks to the local language and culture was carried out in Lusaka, with the assistance of the research faculty and staff at the Human Development Research Unit of the University of Zambia. After preliminary discussion and changes in the tasks, the instructions were translated by a native speaker into Chi-Nyanja, the Lingua Franca of Lusaka, and then translated back into English by another native speaker. This process of translation was repeated until both the author and the local assistants were satisfied with the results. Pretesting the results in several forms with a number of urban and rural children led to further modifications. One task was eliminated entirely. The final procedures are described in the next section.

Since the resulting set of 13 tasks was too long for many of the young children, two overlapping batteries were created. Four tasks were contained in both the A and B batteries; the remaining 9 were assigned to either A or B. Each battery was given in reversed sequence for half its presentations to control for order effects. Thus there were four presentation sequences· (A) digit span, squares, diagonal, face-hands, brothers, Bender-Gestalt, recall, color-form, left-right, and rotation; (A') Same but opposite order: rotation through digit span; (B) digit span, squares, diagonal, face-hands, contradiction, signal detection, and delayed auditory feedback; and (B') contradiction through digit span in opposite order, with signal detection and delayed auditory feedback remaining at the end to facilitate introduction of the tape recorder. Analysis of variance revealed no significant differences between the two batteries (for the four tests in common), or between the two administrative orders.

The Tasks: Background, Procedures, and Results

Digit Span

The immediate recall of a series of spoken digits is a standard item in mental test batteries such as the Stanford-Binet and the WISC. Although the traditional rationale for this emphasizes the role of attention and resistance to distraction (Rappaport, Gill, & Schafer, 1945; Wechsler, 1944), recent research has played down the effect of visual and auditory interference (Craddick & Grossman, 1962; Guertin, 1959) in favor of "primary memory" (Dallett, 1965). In his review article, Frank (1964) states that the Digit Span Test usually factors onto a dimension of "memory" rather than one of "freedom from distractability." Scores increase substantially during middle childhood, and there is some indication that the test drops in correlation with IQ after the age of five or six (Terman & Merrill, 1962). These facts and its familiarity to Western psychologists suggested it as a useful comparative test. In addition, it conforms with the advice of Nissen, Machover, and Kinder (1935) that "tests which involve imitative functions, immediate memory, ... and which ... are practically without representative content" are most useful when working in non-literate societies.

The stimulus series were taken from Wechsler (1944) and administered, as suggested, at a speed of approximately one digit per second with the voice dropping on the last digit of the series. Following the suggestions of Blackburn and Benton (1957), only the more reliable forward version was used: subjects were asked to repeat both series at a given level of difficulty regardless of their success on the first; and testing was terminated after three successive failures. The maximum number of digits successfully repeated was recorded ~~as the~~ subject's score for this test. An alternate set of digit series, using only the numbers one through five, was used for those subjects who, when asked before testing, were unable to count above five.

It should be noted that the traditional Cewa numbers, with base 5, have all but disappeared as a coherent arithmetic system. The cardinal numbers modzi, wiri, and tatu are commonly heard, but only as synonyms for the European one, two, and three. Most figuring is done in the assimilated European version (e.g., "seveni").

(Insert Figure 3 about here)

Figure 3 shows the median maximum number of digits recalled for each age group in the urban and rural samples. The scores average one point or more below American norms (e.g., Terman & Merrill, 1962). In both samples there is a general increase in memory span for digits with age, (p of F less than .01 in both cases), but only the urban data show any suggestion of a departure from linearity: the greatest increases are between four and six years. The urban children perform significantly better than the rural ones at ages five and six (p of t = .06 at five; p = .01 at six; p greater than .10 at other ages).

The preliminary screening question--"count as high as you can"--demonstrated dramatic increases around age seven in the childrens' ability to count (Figures 4, 5, and 6). The great majority are able by this age to count to five, and many are able to go higher. The apparent urban-rural differences are not statistically reliable.

(Insert Figures 4, 5, and 6 about here)

Color-Form Dominance

A number of studies, using a variety of procedures, have investigated the apparent increase with age in using form, rather than color, as the determining cue in matching visual stimuli to a standard. There is considerable evidence that Western children over six years choose on the basis of form (Descoudres, 1914; Brian & Goodenough, 1929; Colby & Robinson, 1942; Segers, 1926; Corah, 1964; Suchman & Trabasso, 1966). Just under that age, children are said to be largely color dominant (Brian & Goodenough, 1929; Colby & Robertson, 1942) or mixed (Descoudres, 1914). Engel (1935) and Lindberg (1938) present evidence for a weaker trend for use of the color cue dominating until the age of twelve or thirteen. The picture is further confused by the reports of Doehring (1960) and Kagan and Lemkin (1961) who find no consistent age trends. Variations in performance have been attributed to a number of factors: intelligence (Engel, 1935; Lindberg, 1938), education (Honkavaara, 1958; Serpell, 1969b), sex (Lindberg, 1938; Colby & Robertson, 1942; Honkavaara, 1958; Doehring, 1960; Kagan & Lemkin, 1961), personality (Lindberg, 1938; Keehn, 1954; and the related diagnostic procedures of Rorschach), linguistic factors (Doehring, 1960; Suchman, 1966a; Carroll & Casagrande, 1958; Serpell, 1969b), and race and culture (Colby & Robertson, 1942; Suchman, 1966b; Gay & Cole, 1967; Serpell, 1969a). Stimulus factors have also been shown to be of some importance (Huang, 1945; Corah, 1966; Serpell, 1969b).

Testing procedures in the current study were similar to previous ones in asking the subject to choose which of two stimuli is most like a standard stimulus, where one is similar in form but of a different color, and the other is the same color, but of a different form. Six white, plastic-covered cards measuring 7 by 9 inches were used. The standard stimulus was centered in the top half of the card, the two choices being below, side by side. Thus the three stimuli were at the vertices of an imaginary triangle. Each stimulus was one of three forms (square, circle, triangle) and one of three colors (red, blue, yellow). The stimuli were of similar apparent size, the square being 2 inches on each side; the triangle 2.5 inches on each side; and the circle slightly under 2.25 inches in diameter. Card one had a blue square compared to a blue triangle and a red square; card two, a red triangle compared to a yellow triangle and a red circle; card three, a yellow circle compared to a blue circle and a yellow square; card four, a blue triangle compared to a blue square and a red triangle; card five, a yellow square compared to a red square and a yellow triangle; card six, a red circle compared to a red triangle and blue circle. Thus the cards were balanced for position preferences.

The research assistant presented the first card to the subject and, pointing, she said, "Here is a picture of three things. See, one here, one here, and one here. Look at the top one (pointing to the standard) and tell me which of the bottom ones (pointing repeatedly to the two bottom ones) looks like the top one." The procedure was repeated with the remaining five cards. After the subject had answered on the last card, the research assistant pointed to the standard and the bottom figure to which the child had not pointed, and said, "Now look at these two. How are these two the same?" The child's immediate answer, or lack of it, was recorded and questioning was continued (if necessary) until the subject acknowledged that there was a similarity. The other five cards were then repeated in reverse order, the purpose being to test resistance to the implication that the subject had chosen the wrong dimension. This procedure was eliminated if the subject had shown no dominant tendency (five or six answers on the same dimension). At the end, a seventh card was presented to the subject with a blue triangle as the standard, compared to a blue triangle and a red circle. Presumably subjects who gave mixed responses to the tests because of confusion over the instructions might answer this identity item incorrectly.

It may be noted that there was difficulty in formulating the instructions for this task. For example, one of the common terms for "the same" implies "the same form." After consulting with three local research assistants and several other native-speaking adults, a phrasing was chosen that was generally agreed to be unbiased with regard to form and color.

Only four subjects failed to pass the identity item (card seven), a five- and a seven-year-old in the urban sample and a four- and a five-year-old in the rural sample. Their data were removed from the analysis. Figures 7 and 8 show the percentage of children at each age responding on the basis of color (five or six of the six cards), form (five or six of the six cards), mixed (fewer than five on both cues), or having unscorable data (position preference or persistent inability to follow instructions). In both samples the general level of form responding is clearly below that reported for European children (cited above), but by adulthood the scores seem to be within the range reported for the Europeans, Comparison with the Zambian data of Serpell (1969a), although not entirely comparable, reveals no dramatic differences. There appears to be an increase in form responding with age in the urban sample beginning around age six. Among the rural subjects, no four-year-olds respond on the basis of form; from five on there is a plateau which shows no stable increase until the teens.

(Insert Figures 7 and 8 about here)

The most interesting result may be the decrease with age in the percentage of subjects giving mixed responses. In both samples this percentage has dropped to zero by eight years, with occasional reoccurrences thereafter. Some previous studies do not explicitly discuss the treatment of inconsistent data. Figure 9 presents the percentages of form responders based on only those subjects who showed a clear dominance for color or form. The urban data now show a sharp increase between the ages of five and seven, with a smaller increase after nine. The extremely small _ns_ of the rural sample make its curve erratic, and it is difficult to draw any generalization; but it appears similar to the urban sample in shape.

(Insert Figure 9 about here)

Analysis of responses on the repeated presentation suggested that the strongest resistance to change was shown by the color-responding young children and the form-responding older subjects, but the effect was not striking.

Sensitivity to Rotation of Geometric Forms

The inability of the young child to behave differentially toward two objects which differ only in their geometric orientation has been the object of study by Western psychologists and educators for many years. In 1930, for example, Rice showed that young children, in searching a matrix of simple drawings for ones which looked like a standard (a diamond or a spoon), paid no attention to the orientation (vertical or horizontal) of the drawings. At age five, a few subjects selected only those drawings with orientation identical to the standard, and the proportion of children doing this increased until age seven. Davidson (1934) showed that reversal errors in matching forms and words to a standard "decreased distinctly at the mental age of five and one-half years." In a second study (Davidson, 1935), her data suggested that confusion of letters which involved an inversion (e.g., d and p) begins to decrease at a mental age of five and one-half or six, while errors continue until at least the age of seven and one-half for letters involving rotation around a vertical axis (e.g., d and b). Gibson (1963) notes that errors in rotation and reversals of letter-like geometric forms are more frequent than errors involving topological transformation (e.g., closure) at four years of age, but they decline to nearly zero at eight years. The importance of topological transformations, she points out, has been learned by children in the development of object perception, while rotation and reversal are relatively unimportant until discrimination of letters is taught.

There is little information on this type of task for children older than eight years, but the data of Rice (1930) suggest that the sensitivity to rotation may drop, rather than remain level, after the age of seven. Suppes (1966) presents data from a task in which the subject has to choose which of two figures, differing in size and rotation, is most like a standard. They suggest a peak of sensitivity to rotation in the first grade (age six), having increased from nursery school and kindergarten, and decreasing at least through grade six. Huttonlocher (1967) has noted that testing procedures may have a major effect on the results, although her data, too, demonstrate the young child's difficulties with orientation.

Rudel and Teuber (1963) have pointed out the parallel between the young child's difficulty in discriminating left versus right diagonals and the similar difficulties of the octupus (Sutherland, 1957), and rats (Lashley, 1938); goldfish suffer a similar disability (MacIntosh & Sutherland, 1962). Such a parallel fits almost too nicely with the hierarchical view of cerebral organization which White (1966b) has related to the "five to seven shift".

Adult subjects in non-Western cultures seem to show similar difficulties in discriminating some kinds of orientation. Shapiro (1960) demonstrated this with native Rhodesian subjects using the Kohs block design test. The adolescent subjects of Jahoda (1956) in Ghana showed a similar insensitivity on the Goldstein-Scheerer cube test. If requested, however, they could usually correct their copy, suggesting differences in the value placed on orientation rather than a perceptual or analytical deficit. Deregowski (1966a) has demonstrated the difficulty of Zambian subjects in interpreting the orientation of a depicted object. Serpell (1968) replicated the Rudel and Teuber finding in both urban and rural Zambian children. His results are in general agreement with the American data, but show mastery of the oblique discrimination to be delayed by two or three years in the Zambian children. He attributes this lag to the substantial differences in education and environment, pointing out that Jeffrey (1966) focused on the same factors in studying the improvement with age in American children. Suppes (1966) notes briefly that a Ghanaian sample did not show the increase in sensitivity to rotation in the first year of school.

The procedures in the present experiment were similar to those of Rice (1930). A small white card 2.5 inches square was put in front of the child. An outlined diamond, measuring slightly less than an inch and .5 inches on its axes, was centered on the card and oriented vertically. The subject was then given a piece of paper, 5.5 by 8 inches which contained a diamond in the same vertical orientation, along with outlined figures of a square, a hexagon, and a circle. The child was asked to point to the figure on his paper which looked like the one on the card, a request which only some of the very youngest children had difficulty in following. He was then given a felt-tip pen and told to touch it again, leaving a mark. After an approving comment, the research assistant removed both the standard and the subject's paper, and then presented the standard rotated 90 degrees, so the diamond was in the horizontal orientation. The subject was given a second sheet of paper with the same four figures in a different array. The diamond on the subject's sheet was also oriented horizontally. The child was again instructed to mark only the figure which looked exactly like the standard. If on these two training sheets the subject seemed to have difficulty, they were repeated with additional instructions until it was clear that the subject either understood what he was asked to do, or that the task was beyond his present ability.

The first test sheet (pendicular) measured 8.5 by 11 inches and contained 35 individual figures, arranged in a five by seven matrix. Ten diamonds were distributed randomly among the other figures, which were the same as on the practice sheets, (circles, hexagons, and squares). On this test sheet, however, half the diamonds were oriented vertically, and half horizontally. The standard was presented to the child in the vertical orientation and left in view. The subject was told that on this piece of paper there were several pictures like the standard, and he should mark all of the ones that were exactly like the standard. Only if he began to mark figures other than diamonds were any further instructions given.

When the subject was finished, both his response sheet and the standard were removed without comment. In their place were put the second test sheet (oblique) and the standard diamond, now oriented 45 degrees off the vertical, from upper right to lower left. Half the diamonds on the subject's sheet were oriented the same way, and half from upper left to lower right. The instructions were as before.

If on either of the two test sheets the subject marked any of the rotated diamonds, the discrepancy was pointed out to him after completion of the oblique test sheet. "Look, you marked this one which goes this way, while the one up here says to mark only those that go that way."

Considerable emphasis was given to the difference in orientation both verbally and by tracing the figures, but no verbal code for the difference (such as "pointing up") was given. The subject was then given an alternate response sheet, half the size of the first, and told "Now this time mark only the ones that are exactly like this one," the standard. Approval of his performance was indicated at the end.

Figure 10 shows the percentage of children at each age who were able to proceed through the practice trials without difficulty and complete the tasks. (A few of the remaining children were able to proceed to the first test after repeated instructions.) In both samples, many of the youngest children were unable to follow the instructions, with the percentage of successes rising rapidly to nearly 100 at age five or six. The amount of time required to answer each of the test sheets varied from 10 seconds to well over 3 minutes, the median being slightly less than 1 minute. The average time was seen to vary as a function of the task (the oblique set was generally completed more rapidly than the perpendicular one); and by age (the subjects under six or seven years generally taking more than their elders.

(Insert Figure 10 about here)

Figure 11 shows the percentage of urban subjects for each of the two tests and repetitions who marked none of the rotated figures. The urban children make little spontaneous distinction between the rotated and nonrotated figures through the age of seven, after which an increasing number of subjects respond only to the unrotated figures. The apparent sensitivity of a few of the youngest children may be the result of poor search strategies (see below). In the rural sample (Figure 12) all subjects at all ages spontaneously marked at least one of the rotated figures. It is clear from the repetition curves of both samples that, when pressed, many of the older subjects are able to make the distinction between the rotated and the unrotated figures. In the urban sample this ability first seems to appear at age seven, but it is not until the teens that the rural subjects can show any differentiation. The oblique distinction seemed more difficult for both samples.

(Insert Figures 11 and 12 about here)

If we look only at the figures with orientation identical to the standard, we can derive some information about the thoroughness of the child's performance. Regardless of his behavior toward the rotated figures, if he was able to maintain attention to the task at hand, and use an efficient searching strategy, the subject should have marked all five of the unrotated figures. Figure 13 shows the median number of correct (unrotated) figures marked by each age group in the perpendicular task. It appears that the growth curve is largely completed by around nine years in both samples. Results from the oblique trials are similar, and the conclusion is corroborated by an analysis of subjects who marked figures other than the diamond (e.g., circle, hexagon, or square). Such errors were frequent in the young urban subjects but had disappeared by age seven (with the exception of one adult). They were extremely common in the rural children but rapidly decreased as a function of age and progression through the task. On the first perpendicular trial such errors had dropped out after age nine, and on the oblique repetition there were no such errors after age six.

(Insert Figure 13 about here)

Bender Gestalt Test

Since its development in the early 1930's by Bender, the visual motor Gestalt test (Bender, 1938) has seen widespread application. Claims have been made for its validity in assessing native intellectual ability, perceptual acuteness, emotional stability, psychodynamic mechanisms, and the physical integrity of the brain. After an extensive review, Billingslea (1963) concluded that, when used with adolescents and adults, the test could be useful in discriminating psychotic and organic populations from normal subjects. Up until the age of twelve or thirteen, however, its only defensible use, when properly scored, is in assessing intellectual ability. Koppitz, for example, using her scoring system (Koppitz, 1960), has found substantial correlation with WISC scores (Koppitz, 1958) and with achievement and readiness tests (Koppitz, Sullivan, Blyth & Shelton, 1959). In presenting her normative results, Koppitz (1960) points out that "there is a marked drop in score between the age of five and the age of seven. Thereafter the decrease is more gradual, and seems to level off at age nine when sufficient maturity in visual-motor perception has been acquired by most Ss to draw the Bender correctly without any distortions." Smith and Keogh (1963) also report "the greatest change in performance ... between kindergarten and grade two." In neither study were subjects below kindergarten or age five tested.

In the present study, only three of Bender's line figures were used Design A consists of a circle and a diamond, side by side, just touching; design two has eleven columns of three small circles each, the columns being tilted slightly to the left; and design six shows two intersecting sinusoidal lines. These were chosen, after preliminary work, to sample the four summary factors of Koppitz' scoring system (distortion of shape, rotation, integration, perseveration); the three types of designs included by Bender (closed figures, lines, and dots); and Koppitz' observations on which factors and designs might be most responsible for the large change in total score between five and seven (Koppitz, 1968).

Each design was drawn with black ink on a white card measuring 4 by 6 inches, which was then laminated in clear plastic. Testing procedures followed the instructions of Bender (1946). The subject was given a sheet of blank paper and a felt-tip pen, and the first card (A) was placed in front of him. The research assistant told the subject to draw what he saw on the card, to mark his paper so it looked like the standard. No time limit was imposed, and the responses to any questions were nondirective. The procedure was repeated with cards two and six, using the same sheet of paper, unless the subject requested another.

After completing the three drawings, the subject was given design A again, and a piece of transparent tracing paper. With the research assistant holding the paper firmly over the design, the subject was asked to move his pencil over the black lines that he saw on the paper, that is, to trace the design.

The three drawings were scored according to the system of Koppitz

(1960), once by the author, and once by a Western research assistant, without knowledge of the subject's age. The Phi coefficient for the scoring reliability on the 746 scores for the urban sample was .81 and for the 459 scores of the rural sample, .84. After careful comparison, most of the disagreements were resolved to the satisfaction of both scorers. For the eight unresolved scores, those assigned by the author were used for analysis. A total score for each error type was formed by summing across designs. The maximum scores were: distortion, 3; integration, 3; rotation, 2; and perseveration, 2.

Two scores were derived from the tracing of design A. The first reflected whether it was copied as a Gestalt, as two separate figures, or was unscorable (e.g., no closed figures). Presumably, separation of the figures (Koppitz' integration) or reorientation (Koppitz' rotation) indicated an active restructuring of the design, since the proper orientation and placement were clearly visible through the paper. Second, the quality of the tracing of the circle was rated on a five-point scale, from "virtually perfect" (1) to "barely recognizable" (5), in an attempt to assess motor coordination. The criterion used by the rater was how well the subject appeared to have succeeded in making the pencil go as he wanted. The three-point Gestalt score had an interrater reliability (Pearson r) of .92, and the five-point quality score of .61.

Figures 14, 15, 16, and 17 present the total score on each of the four types of errors at each age for the two samples. Both distortion and integration errors decrease substantially with age, the major decline occurring between ages five and nine, and five and eight, respectively. The rotation scores are quite uneven in both samples, while there is a suggestion of a U-shaped curve for perseveration. Analysis of variance indicates that all the age effects are significant beyond the .05 level, except for the urban rotation (not significant) and the rural perseveration ($p = .18$) scores.

Inspection of error curves for each design (that is, before summing) indicates the coherence of each error type was greater in the urban sample than in the rural one. Figures 18 and 19 show this for integration. The perseveration curves (not shown) reveal that design six is largely responsible for the apparent peaking and decline in perseveratön errors.

(Insert Figures 14, 15, 16, 17, 18, and 19 about here)

The Gestalt scores for tracing design A are shown in Figure 20. In both samples there is a sharp increase up to the age of eight in the percentage of children who copied the Gestalt. This rise was somewhat more rapid for the rural children, in part because of the difference in unscorable responses. The quality of tracing underwent a more gradual improvement, as seen in Figure 21. The age trends of both scores are stable beyond the .01 level in both samples.

(Insert Figures 20 and 21 about here)

The amount of time required for each drawing varied considerably, from subject to subject, and design to design. In both samples, subjects tended to take more time with age (p of F less than .01), with a sharp increase for the urban children around age seven when they start school. The rural performance was more variable, with a curious peak at age eight on all three designs. In both samples, those subjects who spent longer on the design also looked up at the model more often.

Drawing the Diagonal

The emerging ability to copy a diagonal has been explored in detail by Olson (1968). Five-year-olds, he has shown, can recognize diagonals and sort them from non-diagonals. They are likely to fail, however, in reproducing a diagonal of checkers on a checkerboard, even though the motor responses required in this task are demonstrably within their ability. They can recognize their failure, but are unable to point out the specific error. Olson further demonstrated that verbal instruction in specifying the necessary attributes produced a significant increase in success, but that non-verbal rehearsal of a sorting procedure did not. The explanation offered by Olson rests in a Piagetian framework of cognitive representation. What the unsuccessful five-year-old cannot do is call forth the conceptual attributes of the diagonal (such as starting in a corner, being a straight line, and ending at the opposite corner) and produce these attributes in serial coordination with the whole.

In the present study the subject was given a piece of paper measuring 8 inches square, with a square 2 inches per side outlined in the center. A similar sheet, with a diagonal drawn from upper-right to lower-left was presented as the standard for the subject to copy. The research assistant, pointing to but not tracing the diagonal on the standard, told the subject: "Put this line on your paper, so your paper and my paper are the same." Each response was scored by the author and a Western research assistant, without knowledge of the subject's age, as being either (1) correct, (2) having an error (e.g., starting in one corner but curving to end on a side) or (3) complete failure (e.g., a horizontal line or a circle). The interrater reliability (Pearson r) of this scoring was .98. Responses in the first two categories were analyzed for their orientation being correct (upper right to lower left) or reversed (upper left to lower right).

In the urban sample the ability to draw a diagonal correctly appeared at age five and increased thereafter (Figure 22). Only three children (two seven-year-olds and one nine-year-old) who correctly started their diagonal were unable to finish correctly. In the rural sample (Figure 23), the ability appears more gradually with at least one subject at most ages in the transition category (error). It is not until age seven that a totally correct response was given. Both samples show a rapid fall in the percentage of subjects unable to start the diagonal correctly, from 100% to 0% between ages four to seven in the urban sample and five to nine in the rural one.

(Insert Figures 22 and 23 about here)

It is not until age five or six, therefore, that we can begin to assess the accuracy of the orientation of the drawing (Figure 24). Even in the urban sample accuracy is not greatly above the chance 50%, but there does appear to be some increase with age. (The apparent high success of the five-year-olds is misleading because of the extremely small n.) In the rural sample it is only at the upper ages that the subjects are numerous enough to suggest any generalization, and performance is only slightly above the chance level of 50%.

(Insert Figure 24 about here)

Discrimination of Right and Left

The ability to reliably distinguish one's right hand from one's left develops when the child is about six years old. As Piaget (1959) has pointed out, the sense of objective left/right, necessary for identifying the right hand of someone facing the subject, does not develop until later. Piaget sees this ability as part of a generally increasing accuracy of localization and orientation, and a decrease in egocentricity. Benton (1959) relates it to symbolic verbal abilities, and their emergence around age six.

The English words "right" and "left" have been partly assimilated into Chi-Nyanja. For testing, both the English and the Nyanja (Cewa) were used in case one was unfamiliar to the subject. He was first asked, "Which is your right hand? Show it to me." If the child seemed unable to understand the question, or answered it wrong, he was asked "Which hand do you eat nshima with? Show it to me." (Nshima, the universal corn meal staple in the Zambian diet, is traditionally eaten with the right hand, while the relish is handled with the left.) If the child was able to answer the question in this form, the nshima/relish distinction was used instead of the right/left throughout testing. After the first question, the research assistant responded "good" if the subject was correct, and made no response if he was wrong.

The child was next shown a small doll facing him. "Which is the doll's right hand?" he was asked; "Touch it with your hand." Again there was no correction, and the research assistant continued: "Now touch her left hand." The child was next asked, "How do you know that this is the doll's left hand?" These three questions were then repeated with the doll turned around so that its back was to the child. If the child's answers were not consistent with each other (that is, the same hand always called "right"), the child was told to hold the doll's right hand. The doll was then slowly rotated back to the face-to-face position and the child was asked again, "Now which is the doll's right hand? Why?"

Nearly 60% of the four-year-olds in the urban sample were tested using the "right/left" distinction and by eight years of age all subjects understood this form. However, three four-year-olds (43%) and one five-year-old (10%) responded incorrectly to both forms of the question (right/left and _nshima_/relish). In contrast, none of the rural four-year-olds understood "right/left", and by age eight only 60% could do so; but all subjects answered at least one form of the question correctly.

Very few of the young children in either sample were able to transpose and correctly identify (i.e., consistent with their previous answer) the right hand of the doll facing them. The general increase of this ability, which starts around five, seems to show no reliable discontinuities with age (Figure 25). The relatively high success of the urban four-year-olds has no obvious explanation. Most, but by no means all, of the subjects in both samples were able to answer the next question, with the doll facing away, in a manner consistent with their earlier answer for themselves, as shown in Figure 26. The responses to the "How do you know?" questions showed considerable differentiation with age. Answers ranged from "I just know" to concise statements of the principle involved, but generally fell in two categories: those which indicated an awareness of the issue of objectivity, and those that did not. As shown in Figure 27, it is not until the eighth year that the urban children begin to give an objective rationale. With one exception, this does not appear in the rural sample until age nine. The results of the retesting procedure were too confused to yield any information.

(Insert Figures 25, 26, and 27 about here)

Drawing Maximum and Minimum Squares

As an example of the child's growing ability to use "asymmetric relation groupings $(A < B < C)$" as he enters into the stage of concrete operations, Piaget describes an experiment by Rey: "A square with sides a few centimeters long is drawn on a sheet of paper which is also square ..., and the subject is instructed to draw with a pencil the smallest square he can, as well as the largest square which can be made on such a sheet. Now while adults (and children over the age of 7 - 8) succeed straight away in producing a square of 1 - 2 millimeters and one closely following the edge of the paper, children under the age of 6 - 7 at first draw only squares scarcely smaller and scarcely larger than the standard, and they proceed by successive, and often unsuccessful, trial and error, as if they at no time anticipated the final solutions" (Piaget, 1960, p. 37). What the older but not the younger subjects are able to do is place, in thought, the perceived square "in a series of potential squares, becoming bigger and bigger or smaller and smaller in relation to the first" (Piaget, 1960, p. 30). The ability to construct and use this kind of grouping is a landmark of concrete operations.

The materials used in the present study consisted of a piece of white paper measuring 8 inches on each side with a 2-inch square drawn in the center, and a similar piece of paper without the drawing. The research assistant traced around the square on the first sheet of paper with her finger and said to the subject, "Do you see this?" Then handing him a felt-tip pen she said, "I would like you to draw me another one just like this except make it as big as possible. The biggest square you can possibly draw." When the child had done so, she said: "Good. Now draw another square, but this time make it as little as possible. The littlest square you can possibly draw." Great emphasis was put on the references to size. No cues were given regarding the placement of the squares; if the subject pointed and asked "Here?" he was answered, "Anywhere you want, but as big (little) as you can." Then, unless the subject's drawings were nearly perfect, he was given the second, blank sheet of paper and asked to draw another minimum and maximum square.

Repetition of the task without the model square was introduced after pretesting suggested that the presence of the model influenced the nature of the task. A number of subjects seemed to make unnecessary and detrimental assumptions regarding the placement of their response. For example, that the small square must be concentric with and outside the model, thus restricting it to at least the size of the model. Or, more commonly, that the large square could not be concentric with the model, thus limiting its size to the areas between the centered square and the edge of the paper. Any unnecessary assumption about the concentricity of the response thus interfered with one of the two required tasks. On the second, blank sheet of paper, it was thought that the problem would not arise. However, it appears that some subjects continued to restrict the placement of their maximum square by not allowing it to be concentric with the prior, minimum square. Thus in addition to testing the cognitive operations as described by Piaget, the task contained an element of insight concerning limitations on the placement of the squares.

Figures 28, 29, 30, and 31 present the median area of the large and small squares, with and without the printed model, for each age group of the urban and rural samples. Performance improved dramatically with age in the urban sample, (e.g., p of F for large area with model = .004). The major decrease in the minimum square occurs between five and eight years; increases in the maximum square seemed largely linear. Age effects in the rural sample are not particularly stable. The curious peak at age six for both maximum and minimum squares seems to be related to the large percentage of children drawing the squares concentric with the model at this age, as indicated in Figure 33. The six-year-olds were also the most likely, on the blank sheet, to draw their two squares concentric. The urban children showed no major discontinuities with age in use of concentricity (Figure 32). There was some tendency (not shown) to line up at least one of the edges of the various squares (when concentricity was not used) beginning at age four or five in the urban sample, and six or seven in the rural one.

(Insert Figures 28, 29, 30, 31, and 32 about here)

There was a dramatic increase with age in the quality of the square drawn, regardless of its size. Each response was scored by the author, without knowledge of the subject's age, as (1) a circle or free form; (2) containing some semblance of corners; (3) a definite rectangle; or (4) a square. Good squares were rare. Figure 34 shows the percentage of children at each age who made some attempt at drawing corners on their figures. ($\underline{p}$ of $\underline{X}^2$ of percentage by age less than .000 for each curve.) Equally dramatic but more representative, is Figure 35, which shows the median score at each age. Most growth occurred between the sixth and seventh years.

(Insert Figures 33, 34, and 35 about here)

Brothers

In discussing the emergence of the class inclusion grouping during the concrete operations phase, Piaget (1959) points out that it is not until the age of seven or eight that the child can count himself as being the sibling of one of his siblings. Thus A may have one brother, B, but when asked how many brothers B has, A will respond "None".

There is no directly analogous word for brother or sister in Chi-Nyanja or Chi-Cewa. There does exist, however, the word mlongosi, which in normal usage means "opposite-sex sibling." (Like "brother", it can be given a more general meaning.)

The subject was asked, then, how many alongosi (plural form) he had. If any confusion arose (stemming, for example, from the practice of polygamy), the question was specified to mean opposite-sex siblings of the same biological mother. The child was then asked to name the siblings, and using the name of the first one mentioned the research assistant said, "Now let's talk about (Chidoti). How many alongosi does (she) have?" The child was then asked to name the siblings (of Chidoti).

A number of subjects at all ages found this task extremely difficult, as manifested by considerable hesitation before giving the answers, and occasional difficulty in giving the names of one's siblings. One seven-year-old girl claimed she could not think of her sister's name. When asked to look at the children playing outside the mobile laboratory and see if she was there, she replied "yes," and pointed her out. When asked the name of the girl she had just pointed to, she said without hesitation "Maria." Even among adults the whole series of questions brought forth a reluctance and hesitation not entirely understandable by the Western investigator. One Zambian who had a Western university education explained the situation this way: "To be questioned by a stranger about one's family is extremely threatening. To be asked about one's brother's brother, when one has just spoken about one's own brothers, is to imply somehow that one does not belong to one's family, that there is a cohesive family unit without one's self. Even I, who am used to Western ways, find the topic a bit embarrassing." Several alternatives which would probe related cognitive groupings were tried (such as asking if one would be a stranger in Malawi, and whether Malawian would be a stranger in Malawi), but all seemed to involve more procedural difficulties than the sibling question. Continued work might have produced a better question.

Figures 36 and 37 present the results for the urban and rural samples. Answers were categorized as being either mature, egocentric, or other (e.g., I have one brother, John; John has 15 brothers). In both samples mature responses did not occur until age seven, after which they increase in number. Idiosyncratic responses predominated until age six in the urban sample and age eight in the rural sample.

(Insert Figures 36 and 37 about here)

Sensitivity to Contradiction: Object Invariance

The three previous tasks related to the work of Piaget (brothers, left-right, and maximum and minimum squares) were designed to tap processes only peripherally related to the conservation tasks. Since conservation is the only Piagetian problem that has seen wide application in cross-cultural research, it seemed desirable to include one of this type in the present battery. However, because of the difficulties in translation of the procedures (cf. Heron & Simonsson, 1969), and the often lengthy questioning which has been shown to be desirable (e.g., Greenfield, 1966), an attempt was made to probe some aspects of the appreciation of invariance of objects through an entirely different method.

Charlesworth (1967) has suggested that the absence of a belief in the invariance of the size of an object across spatial transformations may be revealed in response to the trapezoidal illusion. When presented with a plane drawing of two identical trapezoids, most Westerners report that the top figure appears larger in area. Presumably, this effect is the result of compromises the visual system must make among cues in the stimuli. Following Gregory's explanation (Gregory, 1966) of the Muller-Lyer type illusions, the Western eye sees depth in the figures and makes an effort to preserve size constancy of the rectilinear plane receding in the distance. At the same time, the spatially contiguous parts of the trapezoid (the short top of the bottom one, and the long bottom of the top one) are manifestly different in length on the two dimensional paper. The erroneous conclusion that the top trapezoid is larger may be the compromise arrived at for these two conflicting cues. In any event, the phenomenon seems reliable for Western subjects.

If the position of the two trapezoids is reversed, the top one still appears larger, but the contradiction (that first trapezoid A was larger but now B is larger) usually reveals to the adult that an illusion is involved. However, if a young child has not yet learned that such physical characteristics of objects as size are not transformed when objects are spatially rearranged, he may not show any surprise to the change.

In the present experiment one red and one white trapezoid were used, each with bases of 6 and 3 inches, and a height of 2.5 inches. They were made of colored cardboard and laminated in clear plastic. In testing, they were placed one above the other (balanced across subjects for color) directly in front of the subject, who was asked to touch the larger figure. Labeling the subject's response, the research assistant then said, "Oh, the (red) one is bigger. Now watch this." The assistant then moved the figures to reverse their positions so that the trapezoid which had been on top was now on bottom. The assistant again said "Point to the bigger one." The subject's answer along with any indications of surprise were recorded. If on the second trial the subject pointed to the same position as on the first, he was asked, "How can it be that first the (red) one is bigger than the (white) one?" Regardless of the subject's response on the second trial, he was next asked if the two trapezoids were the same size, and then if they were different sizes. Lastly, as a check on understanding of the instructions, a blue trapezoid of the same proportions but obviously greater size was presented with the white figure positioned above it. The long base of the white trapezoid was noticeably longer than the top of the lower, blue trapezoid. The subject was asked to touch the larger figure.

The results were generally unsatisfactory, and they suggest that the data are not able to speak to the intended question of sensitivity to contradiction of object invariance. First, many subjects in both samples "failed" the check item by pointing to the objectively smaller white triangle (Figure 38). This suggests that the judgment was made entirely on the basis of the two adjacent edges. A few subjects were unable to give any coherent answer to this item. Second, up until age six, a substantial number of subjects in both populations answered that yes, the two trapezoids were the same size, and that yes, the two trapezoids were different sizes. Lastly, and most importantly, the top trapezoid was by no means the universal choice on trial one, suggesting that the necessary illusion was either different, or weaker, for the Zambian subjects than for Westerners (Figure 39).

(Insert Figures 38 and 39 about here)

If the perception of the illusion depends on the presence of depth cues, as suggested earlier, there are theoretical reasons to expect that the illusion was marginal for the Zambian subjects. The data of Segall, Campbell, and Herskovitz (1966), and its re-evaluation by Deregowski (1967), demonstrate that the use of depth cues in such illusions depends upon certain kinds of perceptual experiences. The continuous forest growth on the Cewa lands, though not dense, allows little experience of sweeping horizontal vistas, and little chance to learn the visual inferences Segall et al. postulate as necessary for the horizontal-vertical illusion. Moreover, the rural sample had virtually no experience with representing depth in two dimensions, and there is ample demonstration that such experience is necessary for correctly using two-dimensional depth cues (Deregowski, 1966a, 1966b; Hudson, 1962a, 1962b). The urban children, in contrast, live in a visually more open environment, and are far more likely to have had experience with pictorial representation of depth, especially in school. It appears from Figure 39 that susceptibility to the illusion may be greater among the urban subjects. However, the instructional difficulties were no less in that sample, and the results in general seem of little value for the present investigation.

Organization of Free Recall

Changes during the early school years in a child's growing ability to form and use conceptual categories has been the object of study by numerous researchers using a variety of techniques (Kendler & Kendler, 1962; Kuenne, 1946; Inhelder & Piaget, 1964; Piaget, 1953; Bruner, Olver, & Greenfield, 1966). The starting point for the present task was a study by Annett (1959) in which she focused on changes during middle childhood in the use and explanation of conceptual sorting. She presented her subjects with 16 cards, each of which contained a simple line drawing. Four cards portrayed animals, four plants, four vehicles, and four articles of furniture. Subjects were asked to sort the cards into groups that go together, and were then asked for an explanation of the sorting. "The most frequent response at years five and six," she reports, "was to make no sorting at all; at seven and eight to sort the cards in eight pairs, but at nine and over to make four or five groups" (Annett, 1959, p. 225). By eight years, all the subjects were able to produce at least one sorting. When the sortings were scored according to a priori groupings, the most striking result was the dramatic increase in sorting by categories (i.e., animals with animals, not animals with plant or vehicle, etc.) from 43% at five years to over 90% after age eight. The explanations showed a corresponding but somewhat delayed increase in the use of similarities between the objects and use of class name.

Preliminary work with American subjects corroborated the fact that a substantial number of children under the age of seven would be unable to perform such a task. In the hope of collecting similar data without demanding so much of the young subjects, the general design of Annett's work was superimposed on the free-recall technique used so successfully by Bousfield (1953), Tulving (1962), Cole and Gay (in press), and others. The usefulness of this procedure stems from the fact that the subject, when asked to give back a series of words which he has heard or seen, rarely repeats them in the original order: in the process of storing and retrieving the words, the subject imposes an organizational structure.

Success in recalling the stimulus words has been shown to be related to the degree of organization (Tulving, 1968), use of the visual mode (Horowitz, 1969; Rossi & Rossi, 1965), verbal labeling of the stimuli by the subjects (Horowitz, 1969; Hagen & Kingsley, 1963), and, to some extent, age (Horowitz, 1969; Willner, 1967). The amount of clustering (organization) in the recalled lost seems to be responsive to a somewhat different set of variables. Willner (1967) has shown that items belonging to cohesive concepts are more likely to be clustered than those belonging to more diffuse ones, and Cofer's review (1965) amply demonstrates that the clustering can be superordinate, or associative, or idiosyncratic, depending upon the specific cues built in by the experimenter. Rossi and Rossi (1965) have shown that with clear semantic categories present in the stimulus, even four-year-olds recalled words more frequently by category clustering than be serial ordering of the responses. Rossi and Wittrock (1967) replicated this finding on four-year-olds using stimulus words controlled for associative strength.

Evidence on the relation between clustering and age is uneven. Several studies suggest a general increase in clustering with age (Bousfield, Esterson, & Whitmarch, 1958; Mandler & Stevens, 1967; Willner, 1967; Moelly, Olson, Holmes & Flavell, 1969). Rossi (1963) has presented data indicating a monotonic increase in category clustering with mental age, within the range of four to ten years. But Horowitz (1969) failed to find an age effect between five and eight years and Laurence (1967) obtained equivocal results with nursery and kindergarten children.

Since the question in the present study is whether children of various ages use different dimensions when categorizing objects, the stimulus words were chosen to be open to categorization by more than one scheme: cow, bird, monkey; tree, grass, corn (maize); axe, hoe, and "slasher" (a bladed, golf club-like hand tool for cutting tall grass). The a priori methods of association were intended as class (animals, plants, tools); spatial contiguity (bird in the tree, cow eating the grass, and monkey eating the corn); and functional use (axe on the tree, caring for the corn with the hoe, and cutting grass with the "slasher"). Natives of the culture agreed that these were reasonable associations.

It is important to note an unusual aspect of this list. Although it is like the previously used lists in that words can be grouped into mutually exclusive groups (animals), the classes have a number of cross associations. These associations (contiguity and function) are not exhaustive, in that neither type alone can group all the words: contiguity pairs the animals with the plants, and function pairs the plants with the tools. Thus it lacks the symmetry of Willner's list (1967), and the analytic procedures by Cole and Gay (in press), are not entirely suitable.

A single colored drawing of each of the stimulus words was prepared by hand on an 8.5 by 11 inch sheet of white paper. No depth was represented in the drawings, and recognition of the objects proved not to be difficult. Covered with plastic, these nine pictures were assembled in a looseleaf notebook in the following order: tree, cow, corn, slasher, monkey, axe, grass, bird, hoe. The book was presented to the child with the comment "Here are some pictures," and the child was asked to name each picture. If there was hesitation in the naming, he was told the name and asked to repeat it. The stimuli were presented at an approximately constant rate of 2 to 3 seconds per picture. After all nine pictures had been identified, the book was closed and the child was asked to say aloud the pictures he remembered. When the child had finished responding (or the end of 90 seconds), the procedure was repeated with the reminder to "remember what you see, so you can say them afterwards." A total of three trials was given before proceeding to the next task. At the end of the battery (about 10 minutes later), a fourth recall opportunity was given, but on this last trial the pictures were not shown. Finally, a constrained association task was given, by asking for each picture "which of the other pictures belongs with this one?"

As for the other tasks, the younger children often had considerable difficulty in following the instructions. Figure 40 shows the percentage of children at each age in each sample who did not encounter problems in naming the pictures or recounting the stimuli they remembered. Reticence during the recall part of the task was the most common problem, which disappeared by age six (rural) or eight (urban).

(Insert Figure 40 about here)

A number of subjects repeated themselves in recalling the stimuli, but this percentage, in urban subjects, dropped nearly monotonically from 25% at age three to 4% of the adults. Although the age difference was statistically significant (p of F less than .05), there appeared no reliable breaks in the curve between four and the leveling off at age nine. The percentages for the rural sample were more uneven, and no generalization is warranted. Intrusions, that is, "recalling" words not included in the stimulus list, were very rare, occurring mostly in the four- and five-year-old urban subjects.

Both repetitions and intrusions were omitted in scoring the total number of stimuli recalled. Figure 41 presents the median number of correct responses at each age on trial one. The age trend (p of F less than .000) becomes somewhat sharper by trial four. The rural sample had more very low scores than the urban sample at all ages, although these were numerous enough to affect the median score only at the lower ages. The apparently sharper rise in the rural performance from four to six years probably results from the initially greater reticence of the youngest rural children.

(Insert Figure 41 about here)

In order to assess the extent and type of clustering in the sequence of recalled words, each consecutive pair of words was scored as belonging to the same noun group (e.g., cow, monkey); related by spatial contiguity (cow, grass); related by function (tree, axe); related by order of presentation (tree, cow); or none of these relations. After reviewing the constrained association responses given at the end of the battery and the accompanying explanations, grass-hoe was also counted as being functionally related. By the same token, grass-bird and monkey-tree were scored as contiguity. The percentage of a subject's scorable pairs (i.e., omitting repetitions and intrusions) falling into each of these five categories was calculated for each trial and their total. In both samples roughly 40% of the pairs were clustered by group, 15% to 20% by contiguity, 15% to 20% by order, and about 10% by function. In neither sample were there any statistically significant differences by age in any of the types of clustering. This appears to be due to similar group means, not to excessive within-group variance.

Two problems prevent the conclusion that age is not a factor in type of clustering on free recall tasks in these populations. The first is the unusual nature of the stimulus list. The variety of possible associations precludes a single dominant base for clustering, unlike most previous work in the area. If the age trends which have been demonstrated by others represent an increase in the ability to utilize a single basis of clustering built into the list, a highly complex list of words might still fail to draw it out. At all ages each subject used a variety of associations, and this variety could mask any growing ability to cluster a particular way.

A second line of reasoning, rather than assuming that the above results are valid and therefore require interpretation, looks to the scoring procedures as a source of error. Although natives of the culture being tested agreed that the scoring procedure was reasonable, any _a priori_ system assumes some risk of misclassifying the associations inside the subject who produced the responses. With one exhaustive, mutually exclusive set of categories which can be applied to the entire stimulus list, an _a priori_ system can be used with dramatic success (e.g., Cole & Gay, in press). But such is not the case here. Nor can approach of Tulving (1962), which imposes no _a priori_ system in seeking structure in the responses, be applied, because of differences in administration of the task and inadequacies in the present data.

One _a posteriori_ effort was made to uncover systematic subjective orderings in the data and it suggests that the apparent variety of sequences was genuine. A coincidence matrix was constructed with each of the nine stimulus words being represented by one of the nine columns and by one of the nine rows. An entry was then made for each sequential pair of words recalled by the subject, at the intersection of the column representing the first word in the pair in the row representing the second word. The cell entries were accumulated for each of the four trials, and for their sum, for all subjects at each age level in both populations. At this point, inspection of the matrix is hampered by the problem of unequal marginals. For example, it may happen that "bird" is usually followed by "tree", and only occasionally by "grass"; but if "grass" is rarely recalled at all, it may not be accurate to conclude that the "bird-tree" association is stronger than "bird-grass". Therefore, using a procedure described by Mosteller (1968), the matrix was iterated until all marginals equalled 100. This procedure maintains the interrelations of the rows and columns (words) while eliminating the problem of unequal marginals (rates of recall). Inspection of these matrices at the various ages, and several attempts at summarizing them, corroborated the earlier indication that within each age group subjects used a variety of associations, and no reliable generalizations about differences between the ages could be drawn.

The Face-Hands Test

Research using the Face-Hands test developed by Bender and his associates (e.g., Bender, Fink & Green, 1951) has shown that reporting the perception of simultaneous tactile stimulation of the face and hand is a behavior which varies with brain damage (Bender & Fink, 1952), mental age (Fink & Bender 1952; Pollack & Gordon, 1959), and altered states of consciousness (Jaffe & Bender, 1951). Pollack and Fink (1962) have provided a brief review of this work. The results are generally consonant with the hierarchical view of neural and intellectual organization, and of particular interest for the present study is the fact that "below the age of six years almost all normal children ... fail to identify both stimuli correctly. The children are face dominant in that they report the face stimulus but not the hand stimulus. Younger children fail to perceive the hand stimulus even when tested with the eyes open (Pollack & Fink, 1962, p. 363)."

The procedures used in the current study are briefer than those of Fink and Bender (1952). Two colorful soft rubber "ticklers" were shown to the child with the explanation by the research assistant that "now we're going to play a guessing game. He (the author) is going to touch you with these, maybe one place, maybe two places, and you have to point to where you were touched. But to make the game harder, you must close your eyes." A brief standard pretraining followed, during which the subject was allowed to keep his eyes open and any errors were corrected. The subject was offered, and usually accepted, the opportunity to turn the game around on the experimenter. The standard pretraining usually lasted less than a minute but it was extended when necessary. If after two minutes, the subject still seemed unable to follow the game, the task was skipped.

For the actual testing, the subject sat with his hands palms down on the table in front of him, and his eyes closed. The first item consisted of touching lightly with the "tickler" the back of the subject's right hand. He was told to open his eyes and point to where he had been touched. After his initial answer, he was asked, "Just there, or also a second place?" This procedure was repeated eight more times, the other items being, in order: right cheek; both hands; right hand and right cheek; left hand; right hand and left cheek; left hand and left cheek; right hand; and left hand and right cheek.

Figures 42 and 43 show for the two samples the increasing ease with age of comprehension of the task. The results were most dramatic for the rural sample, in which four out of six of the four-year-olds were unable to perform correctly even with their eyes open on simple items, and the other two were able to proceed only after substantial pretraining. By age eight everyone was at least able to follow the basic instructions, and by nine years, virtually no problems were encountered. There were fewer urban subjects in the "unable" category.

(Insert Figures 42 and 43 about here)

The performance-by-age curves vary somewhat with the particular result displayed. Contralateral items are easier than ipsilateral ones, and since our interest is in the initial emergence of an ability, performance on the contralateral items seems most germane. Figure 44 shows the percentage of children at each age who answered both contralateral items correctly (either spontaneously or after the probe). Starting from nearly zero at age four, the percentage begins to climb thereafter. Again the rural curve is somewhat sharper than the urban one, with the largest increase occurring between the seventh and eighth year. The curve for ipsilateral items is similar, but the increase is both later and slower.

(Insert Figure 44 about here)

The poorer performance of the urban children at ages seven, eight, and nine resulted partly from their greater inconsistency: the percentage of subjects answering at least one item correctly was similar for the two samples. The urban subjects also made an average of three times as many errors on the control items (single and symmetric touches) as did the rural subjects (.23 vs .07). The two single-touch control items were responsible for most of the urban and all of the rural errors. When erring, rural subjects usually added the symmetric part (answer "both hands" to the left hand item), while urban subjects also guessed non-symmetric places.

Signal Detection

In studying the increasing ability with age to utilize a pre-stimulus instruction for selective listening, and the effects of various stimulus characteristics on this ability, Maccoby and Konrad (1967) used subjects ranging from kindergarten through the sixth grade. We can assume that the age range was therefore roughly five through twelve years. Under every condition for which data for this entire range is reported (their figures 2, 3, and 4), the increase in mean score and the decrease in intrusive errors are greater between the ages of five and seven than between seven and twelve. It would have been useful for the present purposes if there were data for younger children, but the phenomenon seemed strong enough to warrant inclusion of a similar task in the present battery.

By slightly modifying the procedures of Maccoby and Konrad (1967), the following task was devised. The child was shown an 8.5 by 11 inch sheet of paper on which there were eight colored drawings: a jug, drum, tree, spear, dog, bicycle, hoe, and small hut. The subject was asked to point to each picture and identify it, which was not difficult. Then a small portable Tandberg model 11 tape recorder was brought out, and a brief explanation about it was given. The child was told that the machine, "like a radio," would talk to him and say the names of the pictures, but he could hear it only if he wore a special hat. The research assistant demonstrated on herself how to wear a pair of earphones, and then put them on the subject. A brief recording was played, repeating some of the introductory comments. This slow and informal introduction to the machine, and likening it to an equally wondrous but more familiar machine, successfully reduced any apparent fear in all but a few of the youngest children. When the experimenter was satisfied that the subject was comfortable with the earphones and tape recorder, the stimulus tape was presented.

The tape contained two voices, one male and one female, which explained to the child that they were going to say the names of some of the pictures on the paper in front of him and he was to point to the one they named. After two simple examples the subject was told that henceforth both persons (male and female) would say the name of one of the pictures, but he should listen to only one voice. Two examples in which the male and female spoke sequentially, were preceded by the instruction by one of the voices to "point only to what I say." After the two stimulus words were spoken, the voice which gave instructions said, "You should have pointed to the (picture named)." After these two sequential examples, the child was told that "now the two voices will talk together at the same time," but that he should still listen to only one of the voices. The prestimulus instruction and the repetition of the correct answer were as in the previous examples, but the two voices spoke simultaneously. After these two simultaneous examples the male voice said, "Here are some more," and the 16 test stimuli were given. The stimuli were preceded by the instruction to listen to one of the voices, but the correct answer was not repeated. The eight pictures were divided into four pairs, each member of the pair being said twice by each voice, one of those times as the correct response, and one of those times as the "noise". These four combinations of four stimulus pairs yielded a total of 16 trials.

Figure 45 shows the percentage of children at each age who were able to complete the task. Failure was usually due to an inability to concentrate and follow the directions, and was evident on the earliest training examples. With one exception, no child under the age of five was able to perform at all on the task.

(Insert Figure 45 about here)

Figure 46 presents the median number of correct responses (out of 16) at each age. The increase in performance with age (p of F less than .01), in both samples seems to occur largely around age seven or eight, with another increase during the teens. (The score for the single four-year-old suggests that an even larger change may occur before five, if an acceptable procedure could be found.)

(Insert Figure 46 about here)

The particular pattern of sounds and the absence of perfect balance in the amplitude of the two voices no doubt contributed to the variation in performance on any one of the items. In order to assess how well the 16 items as a whole were testing the same set of abilities, that is, in order to measure their dominant covariation, a principal component factor analysis was performed on the intercorrelation matrix of the 16 test items, using all subjects. Six factors with latent roots greater than one were extracted, but some unity was evident. With an Eigenvalue of 3.01, the first factor accounted for 28% of the common variance and 19% of the total variance of the items; the next largest factor had an Eigenvalue of 1.70. Assuming that the principal factor is the signal detection ability we are attempting to measure, it was thought that analysis of this factor might prove more revealing than the previous analysis of total correct responses, which includes variance from the other, smaller factors. Following this logic, rotation to a simple solution is undesirable, so factor scores were derived on the first principal factor by the Data-Text program, using a method equivalent to the direct solution matrix inversion procedure outlined in Harmon (1960). Mean scores on this factor show a significant improvement with age (*p* of *F* = .005), but the shape of the curve is not noticeably different from Figure 46.

Delayed Auditory Feedback

Feedback from normal, ongoing speech is available through at least three systems: proprioceptive and kinesthetic cues from the muscular apparatus involved in speaking; transmission of the produced sounds to the ear through the bony structures and other tissues; and transmission by sound waves in the air. This last normally incurs a delay of about .001 seconds (Yates, 1963), and it is well known that a distortion in the delay can cause disruption of speech patterns. This is most familiarly experienced in hearing one's own echo when speaking in a large hall.

Yates (1963) has provided a thorough review of the experimental work on the phenomenon of delayed auditory feedback (DAF). The effects are seen in a deterioration of speech fluency, prolongation of vowels, increased intensity of speaking, repetition of consonants, and various physiological responses by the subject. The extent of disruption has been shown to vary with several characteristics of the subject, the verbal materials used, the amount of delay introduced into the system (.180 seconds is optimally disruptive), and the intensity of the feedback (see Yates, 1963). One of the most striking findings is that by Chase, Sutton, First and Zubin (1961), showing that the average disruption in children aged four to six was significantly less than that shown by children between seven and nine years of age.

The delayed auditory feedback task was given immediately after the signal detection procedure, and the subjects were therefore already familiar with the tape recorder and earphones. A boom microphone on the headset was set at 1.5 inches from the subject's mouth, and the input and playback volumes turned up to about three-quarter maximum. Tape speed was 3.75 per second, which, in the delayed feedback condition, produced a delay of .220 seconds. The function of the microphone was briefly explained to the subject ("it listens to you"). The tape recorder was set to "monitor", producing "simultaneous" (normal) feedback of the subject's speech into the earphones, and the subject was asked to perform the following tasks: (1) repeat three times the word: *idya* ("eat"); (2) repeat three times the phrase *Ulipo apo* ("Are you there?"); (3) point to, and name, each of the eight pictures used in the signal detection task; (4) say the sentence: *Atata amapita ku mudzi* ("The father goes back home."); (5) say the sentence: *Anyamata ndi atsikana athamangira m'tengo* ("The boys and girls run in the bush.") The headset was then taken off and the child asked: whether he heard a voice from the earphones; if so, whose; where the voice seemed to come from; and whether the voice sounded strange. The research assistant then said, "We will do it again, but this time a little differently." With the recorder set for delayed feedback, the procedures were repeated.

There were some difficulties in scoring the protocols because of intrusions and errors in following the instructions, but the following measures were obtained for most sections for most subjects: number of syllables repeated (as in stuttering); number of prolonged vowel sounds; total time to complete the utterance; and a four-point scale of grammatical errors in the sentence. Only two subjects (a five-year-old rural girl and a four-year-old urban boy) were unable to complete the task.

The measure of grammatical disturbance and the number of words repeated both had a very narrow distribution, and produced no useful analysis by age. Repeated syllables were more frequent, especially in the urban sample, but were still rare enough to be of uncertain analytic use:

virtually all such errors were made by subjects between the ages of five and nine.

The differential disruption of speech fluency by age is shown in Figure 47, presenting the average increase in time to complete the utterance (i.e., time under delayed feedback minus time under simultaneous feedback). In an attempt to reduce the variance caused by individual differences in speaking speed, and by minor errors in following instructions by the younger children, the time scores were percentaged (time for delayed minus time for simultaneous divided by time for simultaneous). The results proved similar. The five subtasks did not differ greatly, and the total scores shown accurately represent the subtask trends. The age differences in increase in time are most unlikely by chance (p of F less than .01 for each sample), and it is clear that the younger children show very little disturbance of speech. There is no immediately apparent explanation for the observed sample difference in disruption.

(Insert Figure 47 about here)

In addition to a slower rate of speaking in general under DAF, the older subjects prolonged more syllables and had longer pauses between words and between syllables. The age difference in number of prolonged syllables (Figure 48) is statistically reliable (p of F less than .01 in each sample). That the soundless spaces between syllables and words also increase is shown in Figure 49 for the rural sample. The two curves are for the increase in amount of time (1) actually producing sound and (2) between sounds, for the sentence "Atata Amapita Ku mudzi" (measured electronically). It appears that some younger children actually compressed their speech, while the older ones increased both sounds and spaces. (p of F for sounds = .01; for spaces, .05.) This example was chosen as the clearest, but results for the other sentences, and for the urban subjects, were quite similar.

(Insert Figures 48 and 49 about here)

It is not until the seventh or eighth year that the subjects could recognize that they were hearing their own voice, even in the simultaneous condition. The percentage of subjects who could identify the source of the voice as being the tape recorder increased from zero % of the three- and four-year-olds to about 50% at five, and about 60% or greater from age seven on. Younger subjects tended to attribute the voice to the experimenter, the machine, or some nearby animal or object. Most subjects agreed that the voice sounded strange, but only the teenagers and adults distinguished between the two conditions (simultaneous and delayed). Even in these groups, only 30% were able to make some reference to time in their explanation of the difference.

Discussion and Conclusion

The results can be drawn into three general groups. First, the inappropriateness of a few procedures is suggested by the nature of the resulting data. Second, one task showed no particular sensitivity to change during the fifth to seventh years, although administration was not difficult and the results were ordered Lastly, there are several phenomena which occur repeatedly in the data and which seem similar to the changes outlined for Western children. They imply that the processes behind these changes, if not universal, at least exist in the development of children in two societies with substantial genetic and cultural isolation (urban Western and rural Cewa). These effects, in conjunction with the present urban-rural differences, form a picture of an underlying shift and its relation to cultural forces which is strongly consistent with the original theoretical expectations.

The first category of tasks, whose procedures or assumptions were not appropriate to the samples, includes sensitivity to rotation, sensitivity to contradiction, color-form, maximum squares and organization of free recall. The sensitivity to rotation phenomenon seems to be largely an effect of cultural factors not present in the Zambian samples, especially the rural one. This corroborates the conclusion of Suppes (1966). The sensitivity to contradiction task rested on the trapezoidal illusion which was found to be very weak, if extant at all, in the present samples. The results therefore cannot speak to the intended purpose. In the case of the color-form task, testing problems may have diluted a genuine effect: an approach which promotes greater consistency might reveal a Western-like trend. Similarly in the square[illegible]ks, the particular method of presentation was distracting enough to interfere with some potential results. Finally, the word list in the recall task appeared to be too intricate for the intended purpose.

Digit span worked well in the sense that administration went smoothly and the results are reasonably well-ordered, but the primary data show no evidence of significant change in functioning around the sixth year. Two explanations--other than chance--appear possible. First, there was no solid ground for claiming a dramatic change in the Western scores. It was the change in correlations which appeared most noteworthy. Or second, it could be that the forces producing a sudden change are largely cultural, and the changes are not uniquely related to growth at this age.

The results most germane to the current thesis are, of course, those which show marked change in performance around the age of six years, and four clusters seem to emerge. The first and strongest generalization is that children under the age of five or six are extremely difficult to test. The rapid increase in ease of getting the subjects to complete the testing procedures was most dramatic in sensitivity to rotation, free recall, face-hands, and signal detection (Figures 10, 40, 42, 43, and 45). Not so easily presented by graphs was the pervasive and often baffling impression by the author that there was something about the entire process of sitting down with an adult and being asked questions which have a specific answer which was not appreciated by the four- and five-year-olds. This is also true, of course, in Western cultures, and those few researchers who do work with very young children take a variety of measures to offset the problem. White (1970), working from the Western data, has especially focused on the older child's "sharply enhanced ability to form a system of behavior in accord with a proposition offerrd to the child and then, an ability to maintain the proposition an extended period of time."

Those results involving a general ability for perceptual analysis and integration suggest a second, though possibly related, factor of change around the age of six years. It is best seen in the rapidly increasing ability to draw the diagonal; to make the maximum square with corners, and to not distort and to integrate successfully the Bender Gestalt figures, both freehand and tracing (Figures 22, 23, 34, 14, 15, and 20). It is important to note that these changes are not the result of schooling or specific training with pencil and paper. In the urban sample, the changes occur substantially before the children enter school (with the exception of Bender Gestalt integration freehand), and there appeared to be little if any opportunity for working with such materials in the home. The rural sample, of course, provides an even stronger case--the children are entirely unschooled, have never seen printed materials, and with very few exceptions had never used a writing instrument before. Lines on paper are simply not an element in their lives, yet around six years they rapidly improve in the ability to work with them. Since there is little self-selection by not performing on these variables, the phenomenon is clearly in addition to the testability factor. It may be, of course, that an ability to maintain attention and to analyze visual and auditory information are involved in both phenomena: clearly they allow the subject to display at the moment of testing whatever intellectual abilities he has, and they are likely to have contributed in the preceding months or years to the development of the abilities being specifically tested.

The delayed auditory feedback, signal detection, and face-hands tasks form the third group: they all tap an ability to differentiate and utilize two similar stimuli impinging with near simultaneity. The results of this group are of special interest because of their "primary" quality. They are more "information processing" than "logical thought", cognitive more in the sense of Neisser (1967) than Piaget. If there is a universal non-linearity to development between the ages of five and seven which stems from changes in physiological organization or functioning of parts of the brain, then one might expect those tasks which most directly tap the neural control of behavior to yield the most dramatic and reliable results.

The delayed feedback task deserves special focus: the shape of data makes it one of the most successful tasks, and the simplicity of the task makes the data especially compelling. There is a distinct qualitative (Figure 49) and quantitative (Figures 47 and 48) change in behavior after age five. Because the subject is asked only to repeat a simple sentence, and because the phenomenon is completely involuntary, the task is as much a naturalistic observation as a test. This is reflected in the virtual absence of a testability factor in collecting the data: there was no question of the children's not understanding the "purpose" and "rules" of the procedures and no reticence in responding.

A stimulus processing ability is also seen to emerge around age five in the face-hands task, where it works to the subject's advantage.

The present results do not replicate the especially steep slope of increase during the sixth and seventh years found by Fink and Bender (1952) (perhaps due to procedural and analytic differences), but the overall timing is quite similar.

The difficulty of the younger children in responding to the signal detection task was so great that it shows up best in the inability simply to complete the task (Figure 45). After that, scores in the task, given the ability to finish, increased rather slowly and linearly (Figure 46). It seems that social factors or testability put a high "floor" on scores in this particular method of "signal detection ability". It is unfortunate that a second signal detection task which behaved more like DAF and which was quite non-linear in an American sample (Super, in preparation) was eliminated from the present batteries for technical reasons. That procedure, following Siegenthaler and Barr (1968), measured the decibel shift necessary to detect a signal with and without white noise.

The interpretation of DAF as more sensitive in the present sample to fundamental processing than to social or testability factors, in contrast to signal detection, is supported by the results from a third Zambian sample, of rural schooled children. These data were collected as part of the current project, but the number of subjects was so small that detailed comparison with the other samples did not seem worthwhile. Within this sample, however, the ages (seven to nine) of the 16 subjects were relatively independent of their grade (one to three). The overwhelming majority of performance scores correlated more highly with grade than age. For example, total score on signal detection correlated .60 with age, and .74 with grade (the latter significant at the .05 level).

Only rarely was the difference in correlations significant, but the directionality was overwhelming. In contrast, all the delayed feedback variables correlated more highly with age than grade. For example, increase in time correlated -.75 with age, and -.42 with grade (the former significant at the .05 level). While the problematic nature of these data dictate their location in the Discussion section rather than Results, their implications for our understanding of the five to seven shift are profound. If valid, they strongly support our special emphasis on the delayed feedback results as the task most sensitive to the maturational basis of that shift. (Social factors no doubt also play a role, as suggested by the apparent divergence of results between the urban and rural samples.)

The fourth cluster of positive results may best be labeled cognitive maturity. Three of the tasks related to the work of Piaget and his colleagues belong here: minimum squares, left-right discrimination, and brothers (Figures 30, 31, 25, 27, 36, and 37). All show dramatic improvement during the sixth and seventh years, despite difficulties in adaptation and presentation.

The number of pictures recalled show some non-linearity before and after age six (Figure 41) and this result may be included under the heading cognitive maturity. If this effect is replicable, it is not clear why the memory for digits did not show a similar effect. Two explanations seem reasonable. First, that in spite of both being verbal, the two tasks involve somewhat different kinds of memory processes (e.g., visual vs. numerical), and that these processes are not affected equally by the changes at six years. Or second, that the social situation in the picture task requires more openness to talk and greater test-taking ability than does that in the digit recall task; thus it is more sensitive to competence as a subject, which is a major area of growth, as noted above.

Up to this point in the discussion, little attention has been given to the differences between the urban and rural samples. It should be clear that most weight has been given to the rural sample when considering the question of universality in that it shares far less with Western culture and education than does the urban sample. Tested at each age, relatively few of the apparent sample differences are statistically reliable. But if, in addition to probability estimates we pay some attention to the application of differences at successive age levels and with similar variables, three phenomena seem worth noting in regard to the effects of cultural ambiance and specific training. The examples below should be regarded as illustrations of reasonable abstractions, rather than proven cases in every instance.

The Western nature of the tasks is reflected in the generally superior performance of the more Western urban sample. One factor, without doubt, is the urban children's better understanding of the testing situation: in most cases where ease of understanding the task and responding in some fashion have been quantified, the urban children have less difficulty. This is particularly true in the youngest age group, four years. While one might argue either way that one sample would be more anxious than the other at being interviewed by a white adult, it appears that something in the urban culture has prepared the children for this type of interaction. The present study cannot differentiate between such possibilities as diffusion from the schools and the effect of urban living conditions on daily social interaction. In any event, the differences between samples appears to be less important than the earlier commonality that children under six years are hard to test.

The cosmopolitan, mechanical, geometric, and literate urban culture can also be seen to have a number of direct effects on children's performance on the tasks. Since most often the effects begin before the age of entry into school--although they may increase at this age--we must attribute these effects not simply to schooling but also the cars, signs, "carpentered world", and less traditional values of urban culture. These factors seem to have two kinds of effects: to accelerate the achievement of certain behaviors, which achievement would be gained anyway; and to increase the acquisition of specific skills to a level which is not achieved without the urban supports.

The "Johnny and Jimmy" effect of simply speeding normal achievement (McGraw, 1935) is best seen in the ability to count, and to a lesser extent, the ability to recall digit sequences (Figures 4, 5, 6, and 3). In both cases, the urban sample is ahead of the rural one at the younger ages, but the final adult levels are very similar. That urban children are given more exposure and training in numbers is, of course, an assumption. In any event, this is a more specific instance of the urban precosity found in the general ease of testing.

The last class of sample effects lacks the "catching up" of the rural sample. In almost all of the drawing tasks (e.g., using corners in maximum squares, Bender Gestalt distortion score), the urban sample's superiority increases with age, especially at the age of entry into school.

They achieve at a level of performance never equalled by the rural subjects. One can assume these effects are the result of experience with drawing and writing, and of living in a generally geometric environment. It is interesting to note that the urban adults, who have largely grown up in the same schoolless culture as their rural peers, are also out-performed by their schooled and urbanized children on the Western tasks.

The distinction between these two effects is at least partly artificial, and the sensitivity to rotation task provides an especially instructive example (cf. Jahoda, 1936). Simply asked to mark all figures like the model, the rural subjects never differentiate on the basis of rotation. In the urban sample, children begin to differentiate around age eight, after some schooling; the percentage increases with age (except for the unschooled adults). Urban life and schooling teach most urban subjects that rotation is a dimension relevant to the sameness of printed figures. When specifically requested to discriminate rotation, however, the rural adults perform nearly as well as the older urban subjects under the same conditions. Some urban seven-year-olds will also discriminate. Children under seven are unable to discriminate under any of the present conditions. Thus performance depends on an interplay of maturing abilities, specific training, and cultural implications concerning the expected behavior. There may be no finality of the first two factors independent of the third.

Cultural factors need not always be in favor of schooled, urban subjects, of course. It can be imagined that rural, minimally schooled Appalachian children would perform better on evaluation procedures developed by Cewa psychologists than would urban children from Scarsdale. (For the non-American reader: Appalachia is a rural, poverty-stricken area stretching along the inland Eastern part of the United States; Scarsdale is a well-to-do suburb of New York City, inhabited largely by professionals and intellectuals.) In this sample, the rural subjects perform more accurately than the urban ones on the face-hands test. One reason to believe the difference is real is the special attention that was given to the task by subjects. An elderly adult referred to it as the "witch-doctor one," explaining that touching different parts of the body was part of a traditional routine for diagnosis of illness. If the task was seen by the subjects as related to some traditional activities and values, one might expect the more traditional rural subjects to perform better. Regardless of the facts in this particular case, one cannot ignore the importance of understanding how particular tasks fit into the values, beliefs, and skills of a particular culture. Cole and his associates (Cole, 1970; Gay & Cole, 1967) have pursued this issue with brilliant success. They have, in essence, asked "how must situations differ for peoples of different cultures to perform in similar ways, and what does this tell us of the role of culture in the intellectual workings of the mind?"

Sample differences in the present study are not of direct importance for the hypothesis (although they may warn us where not to generalize): it is the similarities we seek. Yet the thesis is one of a major difference--between himans above and below the age of six or seven years. There may be a "cultural difference" here: as pointed out earlier, the children do not share the implicit rules and knowledge necessary to produce the prescribed behavior in the testing situation. But the dramatic increase in testability in the absence of cultural preparations for the situation and the apparently prior changes reflected in the delayed feedback task support the contention that the change at six is not simply a learning of the rules for testing.

No formal analysis was performed to isolate sex differences because of prohibitively small n's (see Table 1). Visual inspection of differences on the major variables revealed nothing of interest.

Before turning to a final consideration of the "five-to-seven shift" hypothesis in light of these data, let us note the theoretical context into which the hypothesis fits (White, 1966b). A major element of this context is an evolutionary perspective which notes that the structures for higher order functioning have been added over time to more primitive structures in man's brain. The human brain at birth resembles in some ways the phylogenetically earlier state, in that higher controls and organization of the "newer" structures are not yet fully developed. There is ample neurological and physiological demonstration of continued brain growth up to the adolescent years, and an important part of maturation is the increasing role played by the higher centers of the brain.

As the higher levels of control become more dominant, the lower level of organization does not dissolve. Adult functioning reflects both the more basic and primitive aspects, and the more complex cortical controls superimposed on them. Thus in psychological pathology, or neural damage or disruption, when the higher controls are inhibited, the effects of the lower ones can readily be seen (White, 1965; Werner, 1961). Razran (1964), drawing on the work of several researchers, has demonstrated this point for the different types of semantic conditioning in young children, the feebleminded, and those under the effect of drugs or fatigue. He concludes that "the lower level (of our learning potentialities) is not non-existant, but held in abeyance and reasserts itself in periods of lower organismic functioning (p. 215)."

It remains to justify the present data as supporting a phenomenon called the "five-to-seven shift". The attentive reader will have noted that in order to include every instance which has been pointed out as relevant, the phenomenon should rather be called the "four-to-ten shift." At different times the focus was on the beginnings of growth, on its completion, or on an apparent non-linearity in its continuing curve. But the view here claims to be more than just a summary of development in the latter part of the first decade of life. It claims that at some point around the age of five or six there is a fundamental change in the organization of functioning in the brain. The change is of course the effect of continuous growth, but discontinuities in function may occur because of differential rates of growth in different processes, or because of the emergence of a new process. In either event, there is a change in the organization of control that is so fundamental in its effects as to appear qualitative.

It is not necessary to the hypothesis--and in fact it appears not to be true--that all associated changes in behavior begin and end within a span of two years, centered on age six. It would appear rather that a new system or principle becomes introduced, perhaps suddenly, and that the effects of this higher order organization continue to pervade the organism's system for representation of the world and control of behavior. There may be an analogy in the learning of mathematics: at a rather low level, a student may understand simple arithmetic--addition, multiplication, division, and so on. He functions quite well with this system. Within a relatively brief span of time, he is taught algebra--a new organization for his knowledge which both indicates new relationships between the present elements, and also makes way for entirely new content. Under stress or confusion the student may function at a lower level (Skemp, 1962): he may fit specific numbers in the equation to test its validity, or he may count on his fingers. There is a sudden change, it is superimposed on the old structure, its effects pervade over time the entire system, and it provokes new and still more complex content.

These principles, when applied to the present data, suggest that the delayed auditory feedback, face-hands, and signal detection tasks tapped a rather fundamental aspect of stimulus processing and behavioral control by the higher nervous system. This change, we might infer from the present samples and the Western data, occurs in all children. It is manifest in some specific skills, changes in cognitive functioning, and an increased ability to cooperate and perform in the kind of testing situation favored by Western psychologists.

Cultural pressures and training are effective in teaching each child who is able specific skills, be they signal detection, drawing, story-telling, understanding social relations, or whatever. Without specific training, some children may still acquire these skills given enough time for incidental and random learning. That is to say, at a given age, a given percentage of children will be able to perform a certain task, another percentage can easily learn to do so, another percentage can learn with difficulty, and another percentage simply is unable to emit the requested behavior. The more importance assigned to a skill by a culture, and the more learning of that skill it promotes, the less ready a child has to be to acquire the behavior. Thus in a drawing-oriented culture, children under five may draw well relative to children from other cultures. But if all young children cannot draw to a certain criterion and most older children can, the percentage who can will increase rapidly as maturation reaches a crucial point at around five or six years.

The suddenness of the shift may, of course, look different when individual curves are drawn (Estes, 1956). The forms of the present aggregate curves no doubt result in part from the distribution of ages at which the hypothesized shift occurs. Only longitudinal studies with a more satisfactory n can approach this question with any finality.

Note

1. The location of the Teen and Adult groups on the abscissa of the graphs has been arbitrarily set at what corresponds, spatially, to eleven and thirteen years. It is important to remember in reading the graphs that were they properly located (which location would, in fact, vary with the particular subjects represented) the slope of the curves would be noticeably less steep after age nine. For visual clarity in the figures, the abscissa and connecting lines have not been interrupted, which would have visually reinforced the discontinuity.

Because of the small and unequal ns, the quanta by which the percentaged curves can vary is different for the several groups and samples. To aid the reader in studying details of the graph, the n of each age group is reported with the figure caption. Points representing a single subject have been put in brackets.

The lines connecting points have occasionally been omitted for the sake of visual clarity.

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TABLE 1

Age and Schooling - Urban Sample

	Age (in Years)								
Highest Grade Entered	Under 4	4	5	6	7	8	9	Teen (10-17)	Adult (over 17)
0	6	16	18	16	5	4	0	0	5
1				3	14	4	4	1	-
2					4	4	7	3	-
3						4	13	7	1
4							2	13	3
5							1	9	2
6							1	13	-
7								3	1
8								1	4

TABLE 2

Urban Subjects: Age and Number

	Age (in Years)								
	Under 4	4	5	6	7	8	9	Teen (10-17)	Adult (over 17)
Male	5	9	9	9	14	11	14	34	14
Female	1	7	9	10	9	5	14	16	2
Mean Age (in years)	3.0	4.1	4.9	6.0	7.0	7.9	9.1	12.3	36.0
Std. dev. of age	.29	.22	.24	.31	.30	.25	.51	1.5	8.2

TABLE 3

Rural Subjects: Age and Number

	Age (in Years)							
	4	5	6	7	8	9	Teen (10-17)	Adult (over 17)
Male	5	8	8	8	8	8	11	11
Female	1	4	2	3	0	0	4	9
Mean Estimated Age (in years)	(4)	(5)	(6)	(7)	(8)	(9)	13	33
Std. dev. of age	-	-	-	-	-	-	1.9	11.9

Figure Captions

Figure 1 Percent of children with adult mandibular incisors, by age and sample. *N* urban at each age: 16, 18, 18, 23, 24, 27, 49, 16. Rural: 6, 12, 10, 11, 8, 8, 15, 20.

Figure 2 Percent of children able to reach opposite ear, by age and sample. *N* urban and rural: as in Figure 1.

Figure 3 Median number of digits recalled, by age and sample. *N* urban: 16, 18, 19, 23, 16, 22, 41, 16. Rural: 6, 12, 10, 11, 8, 8, 15, 20.

Figure 4 Percentage of children who can count to five or more, by age and sample. *N* urban and rural: as in Figure 3.

Figure 5 Percentage of children who can count to 10 or more, by age and sample. *N* urban and rural: as in Figure 3.

Figure 6 Percentage of children who can count to 20 or more, by age and sample. *N* urban and rural: as in Figure 3.

Figure 7 Percentage of urban subjects responding color-dominant, form-dominant, mixed, and unscorable, by age. *N*: 8, 10, 10, 12, 6, 18, 20, 8.

Figure 8 Percentage of rural subjects responding color-dominant, form-dominant, mixed, and unscorable, by age. *N*: 3, 6, 4, 4, 4, 4, 7, 10.

Figure 9 Percentage of consistent responders who responded form-dominant, by age and sample. *N* urban: 1, 4, 4, 7, 6, 16, 18, 8. Rural: 1, 3, 2, 1, 4, 3, 5, 9.

Figure 10 Percent of subjects completing the rotation task, by age and sample. N urban: 7, 9, 9, 11, 6, 9, 16, 8. Rural: 3, 6, 4, 4, 4, 4, 7, 10.

Figure 11 Percentage of urban subjects discriminating rotated figures, by age and trial. N: 6, 9, 9, 11, 6, 9, 16, 8.

Figure 12 Percentage of rural subjects discriminating rotated figures, by age and trial. N: 1, 4, 4, 3, 4, 4, 7, 10.

Figure 13 Median number of unrotated (correct) figures, by age and sample. N urban and rural: as in Figures 11 and 12.

Figure 14 Mean sum of Bender Gestalt distortion scores, by age and sample. N urban: 7, 9, 9, 11, 6, 12, 18, 7. Rural: 3, 6, 4, 4, 4, 4, 7, 10.

Figure 15 Mean sum of Bender Gestalt integration scores, by age and sample. N urban: 7, 8, 9, 11, 6, 12, 18, 7. Rural: 3, 5, 4, 3, 4, 4, 7, 10.

Figure 16 Mean sum of Bender Gestalt rotation scores, by age and sample. N urban: 4, 5, 9, 11, 6, 12, 18, 8. Rural: 0, 1, 3, 3, 4, 3, 7, 10.

Figure 17 Mean sum of Bender Gestalt perseveration scores, by age and sample. N urban: 7, 8, 9, 11, 6, 12, 18, 7. Rural: 2, 4, 4, 4, 4, 4, 7, 10.

Figure 18 Mean Bender Gestalt integration scores, urban subjects, by age and design. N: as in Figure 15.

Figure 19 Mean Bender Gestalt integration scores, rural subjects, by age and design. N: as in Figure 15.

Figure 20 Percentage of subjects who traced Bender Gestalt design A as a Gestalt, or as unscorable, by age and sample. N urban: 7, 9, 10, 12, 6, 12, 18, 8. Rural: 3, 6, 4, 4, 4, 4, 7, 10.

Figure 21 Mean quality rating for tracing Bender Gestalt design A, by age and sample. N urban and rural: as in Figure 20.

Figure 22 Percentage of urban subjects drawing diagonal correctly, with an error on the end, and complete failure, by age. N: 5, 7, 8, 6, 6, 8, 12, 9.

Figure 23 Percentage of rural subjects drawing diagonal correctly, with an error on the end, and complete failure, by age. N: 3, 6, 4, 4, 3, 4, 7, 9.

Figure 24 Percentage of subjects drawing diagonal with correct orientation, by age and sample. N urban: 0, 2, 7, 6, 6, 8, 12, 9. Rural: 2, 0, 1, 3, 2, 4, 7, 9.

Figure 25 Percentage of subjects responding to doll facing them consistent with answer for self, by age and sample. N urban: 6, 10, 9, 11, 7, 8, 18, 8. Rural: 3, 6, 4, 4, 4, 4, 7, 10.

Figure 26 Percentage of subjects responding to doll with back to them consistent with answer for self, by age and sample. N urban: 6, 10, 9, 11, 7, 9, 18, 8. Rural: as in Figure 25.

Figure 27 Percentage of subjects giving objective rationale for answers to left-right questions, by age and sample. N urban: 6, 9, 9, 11, 7, 9, 18, 8. Rural: as in Figure 25.

Figure 28 Median area of large square, with and without model present, urban subjects, by age. N with: 12, 17, 18, 23, 16, 26, 38, 16. Without: 12, 15, 18, 18, 14, 15, 23, 9.

Figure 29 Median area of large square, with and without model present, rural subjects, by age. N with: 5, 11, 10, 11, 7, 8, 15, 20. Without: 4, 11, 10, 11, 7, 8, 15, 19.

Figure 30 Median area of small square, with and without model present, urban subjects, by age. N with and without, as in Figure 28.

Figure 31 Median area of small square, with and without model present, rural subjects, by age. N with and without, as in Figure 29.

Figure 32 Percentage of urban subjects who drew squares concentric, by trial and age. N: as in Figure 28.

Figure 33 Percentage of rural subjects who drew squares concentric, by trial and age. N: as in Figure 29.

Figure 34 Percentage of subjects who drew large "square" with corners, by trial, age, and sample. N: as in Figures 28 and 29.

Figure 35 Mean quality rating of squares, by age and sample. N: as in Figures 28 and 29.

Figure 36 Percentage of urban subjects giving mature, egocentric, and other answers to the Brothers task, by age. N: 7, 9, 9, 12, 6, 9, 19, 5.

Figure 37 Percentage of rural subjects giving mature, egocentric, and other answers to the Brothers task, by age. N: 3, 6, 4, 4, 4, 4, 6, 10.

Figure 38 Percentage of subjects passing trapezoidal check item, by age and sample. N urban: 8, 8, 9, 11, 7, 10, 21, 7. Rural: 3, 6, 6, 7, 4, 4, 8, 10.

Figure 39 Percentage of subjects choosing the top trapezoid on trial 1, by age and sample. N urban and rural: as in Figure 38.

Figure 40 Percentage of subjects proceeding without difficulty through the recall task, by age and sample. N urban: 5, 8, 9, 9, 5, 7, 12, 7. Rural: 3, 6, 4, 4, 4, 4, 7, 10.

Figure 41 Median number of words recalled on trial 1, by age and sample. N urban and rural: as in Figure 40.

Figure 42 Percentage of urban subjects following the Face-Hands instructions easily, needing extra pretraining, and unable to continue, by age. N: 16, 18, 19, 23, 15, 27, 42, 16.

Figure 43 Percentage of rural subjects following the Face-Hands instructions easily, needing extra pretraining, and unable to continue, by age. N: 6, 12, 10, 11, 8, 8, 15, 20.

Figure 44 Percentage of subjects responding correctly to both contralateral items, by age and sample. N urban: 16, 18, 19, 23, 15, 27, 42, 16. Rural: 6, 12, 10, 11, 8, 8, 15, 20.

Figure 45 Percentage of subjects completing the signal detection task, by age and sample. N urban: 8, 7, 9, 11, 7, 9, 15, 7. Rural: 3, 6, 6, 7, 4, 4, 8, 10.

Figure 46 Median number of signal detection items correct, by age and sample. N urban: 1, 5, 6, 11, 5, 8, 15, 7. Rural: 0, 3, 4, 5, 3, 4, 3, 10.

Figure 47 Median increase in time for speaking under DAF, in seconds, by age and sample. N urban: 7, 7, 8, 11, 6, 9, 18, 7. Rural: 3, 5, 6, 7, 4, 4, 3, 10.

Figure 48 Median increase in number of prolongations while speaking under DAF, by age and sample. N urban and rural: as in Figure 47.

Figure 49 Median increase in time during sounds and between sounds, under DAF, rural subjects by age. N: as in Figure 47.

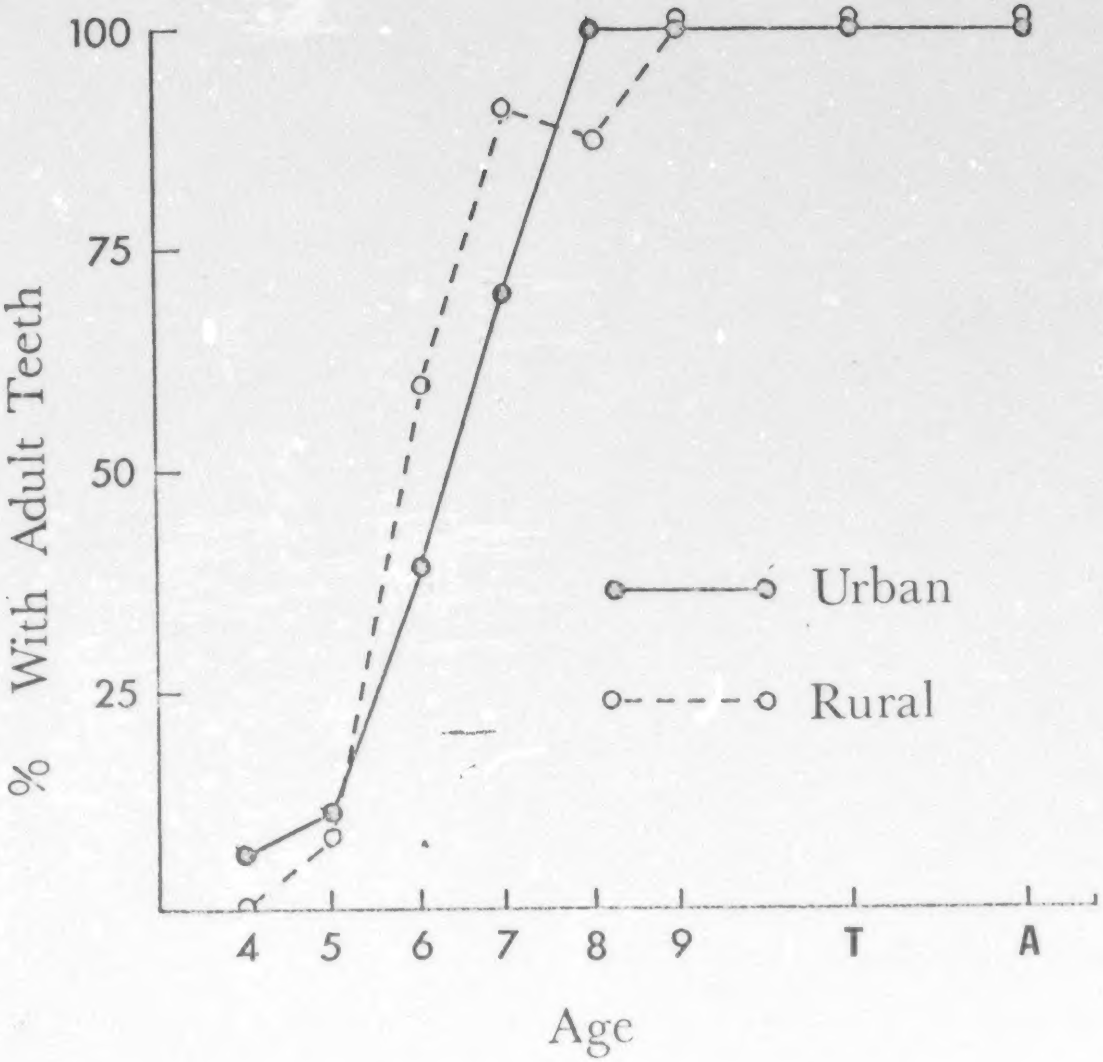


Figure 1 Percent of children with adult mandibular incisors, by age and sample. N urban at each age: 16, 18,18,23,24,27,49,16.; Rural: 6,12,19 10, 11, 8, 8, 15, 20.

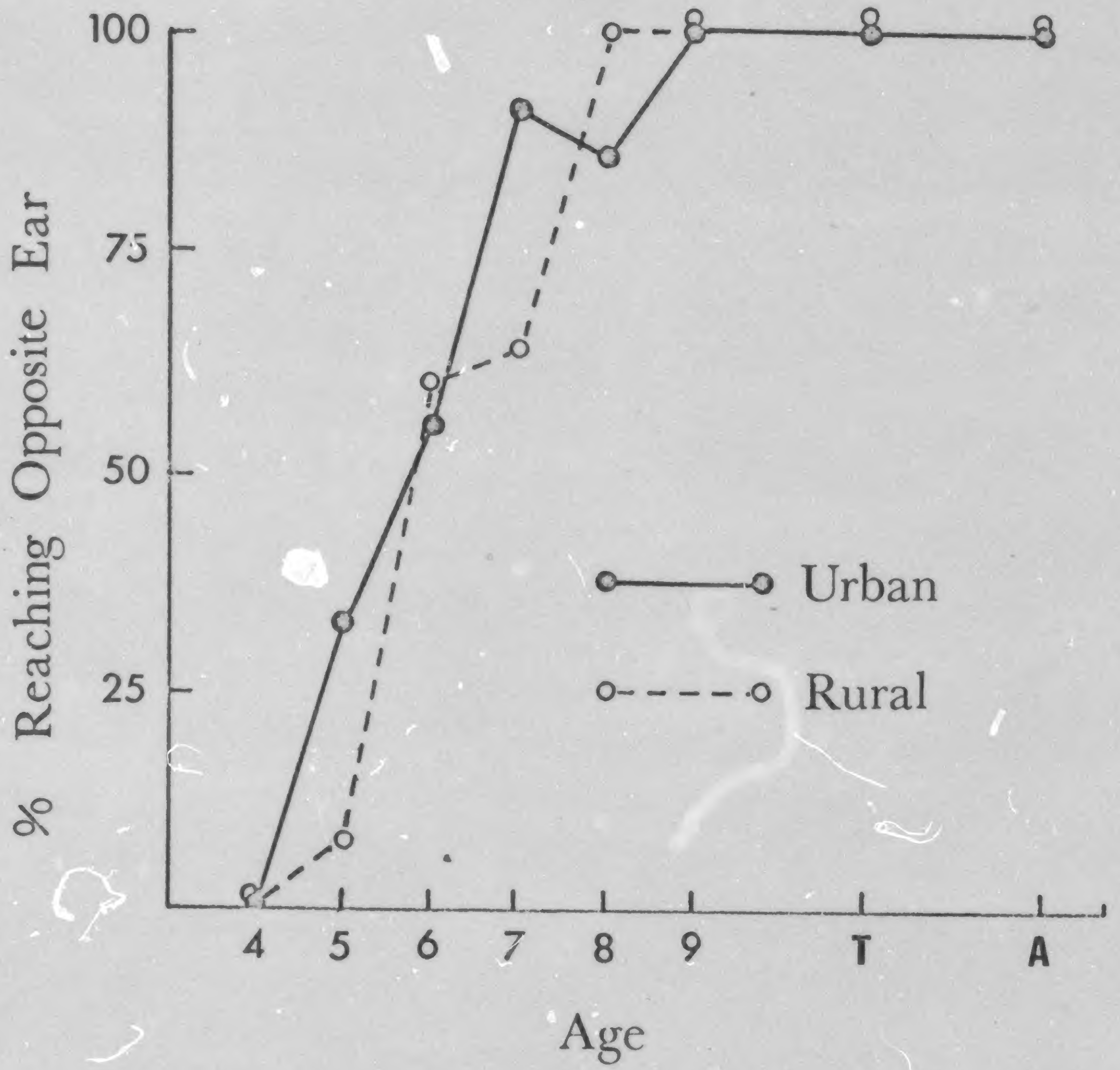


Figure 2 Percent of children ~~with~~ able to reach opposite ear, by age and sample. N urban and rural: as in Figure 1.

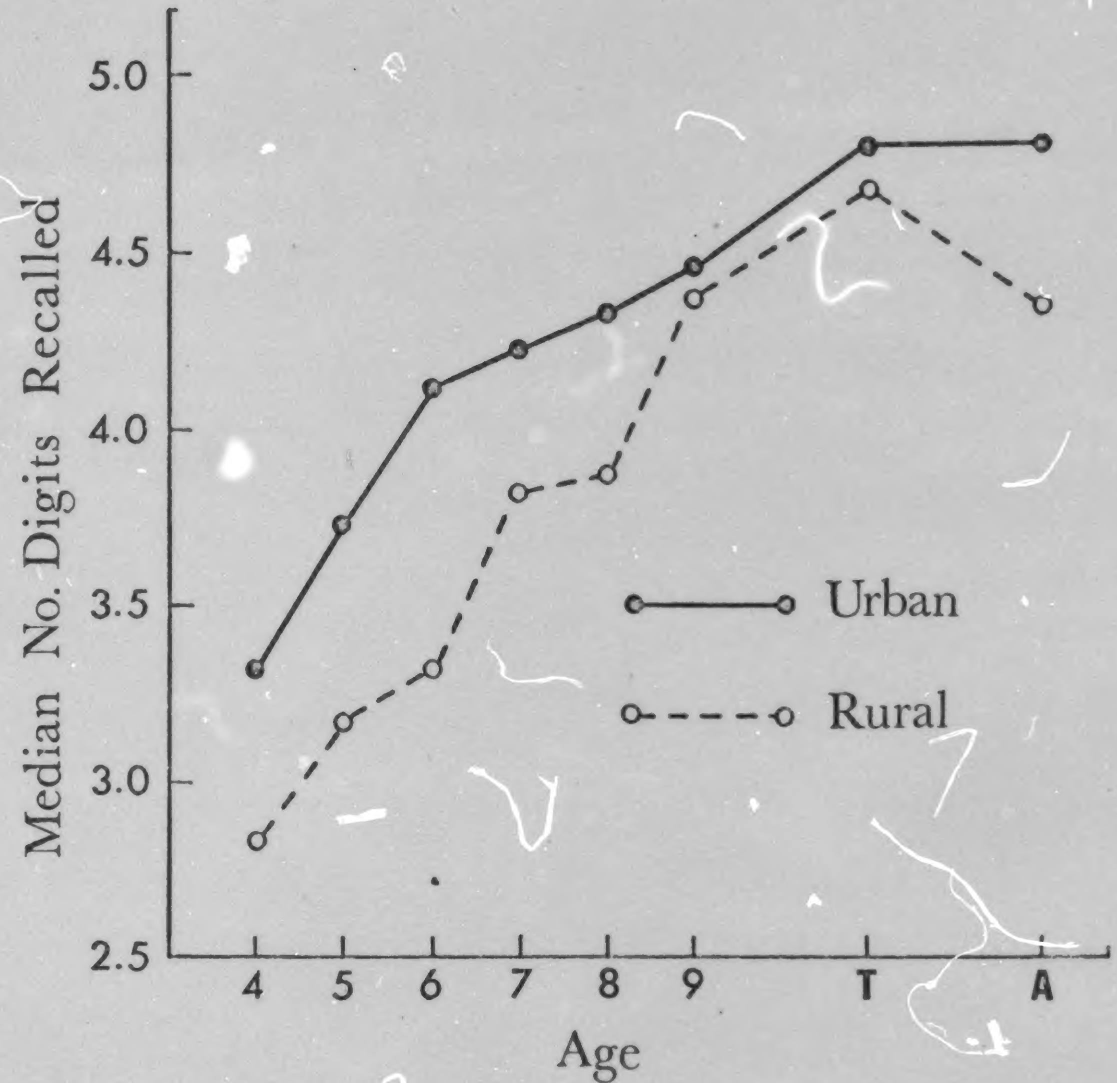


Figure 3 Median number of digits recalled, by age and sample.

N urban: 16, 18 19, 23, 16, 22, 41, 16; Rural: 6, 12, 10, 11, 8, 8, 15, 20.

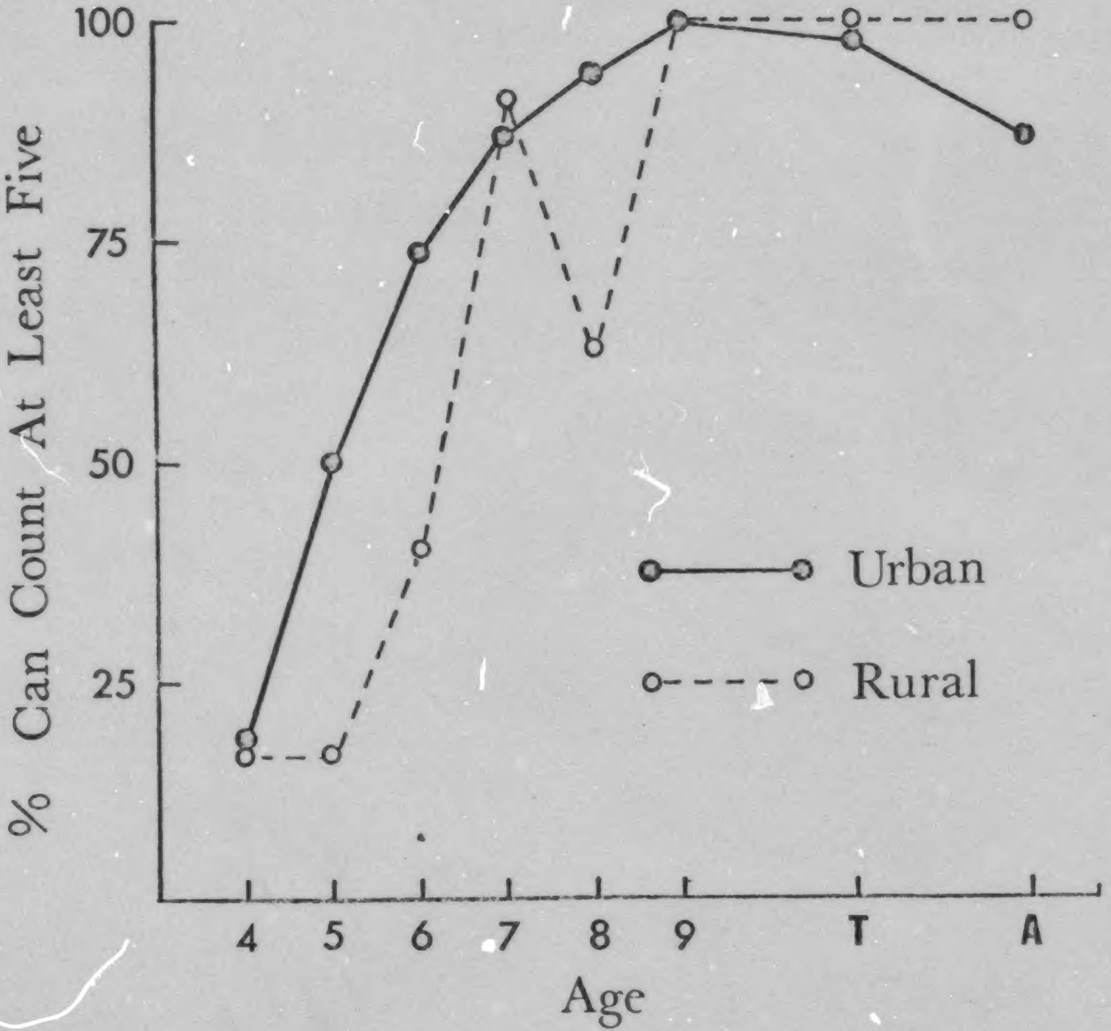


Figure 4 Percentage of children who can count to five or more, by age and sample. N urban and rural: as in Figure 3.

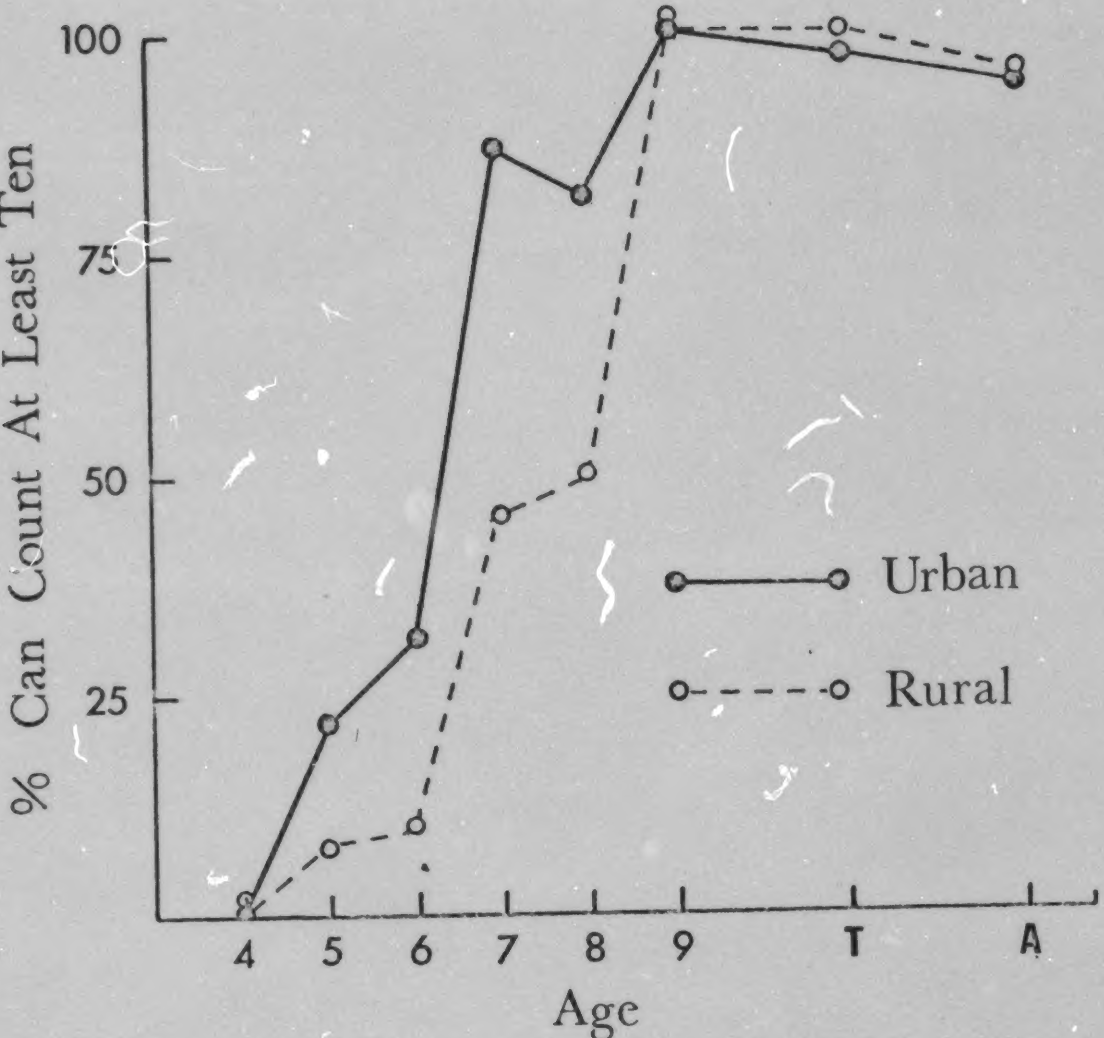


Figure 5 Percentage of children who can count to 10 or more, by age and sample. N urban and rural: as in Figure 3.

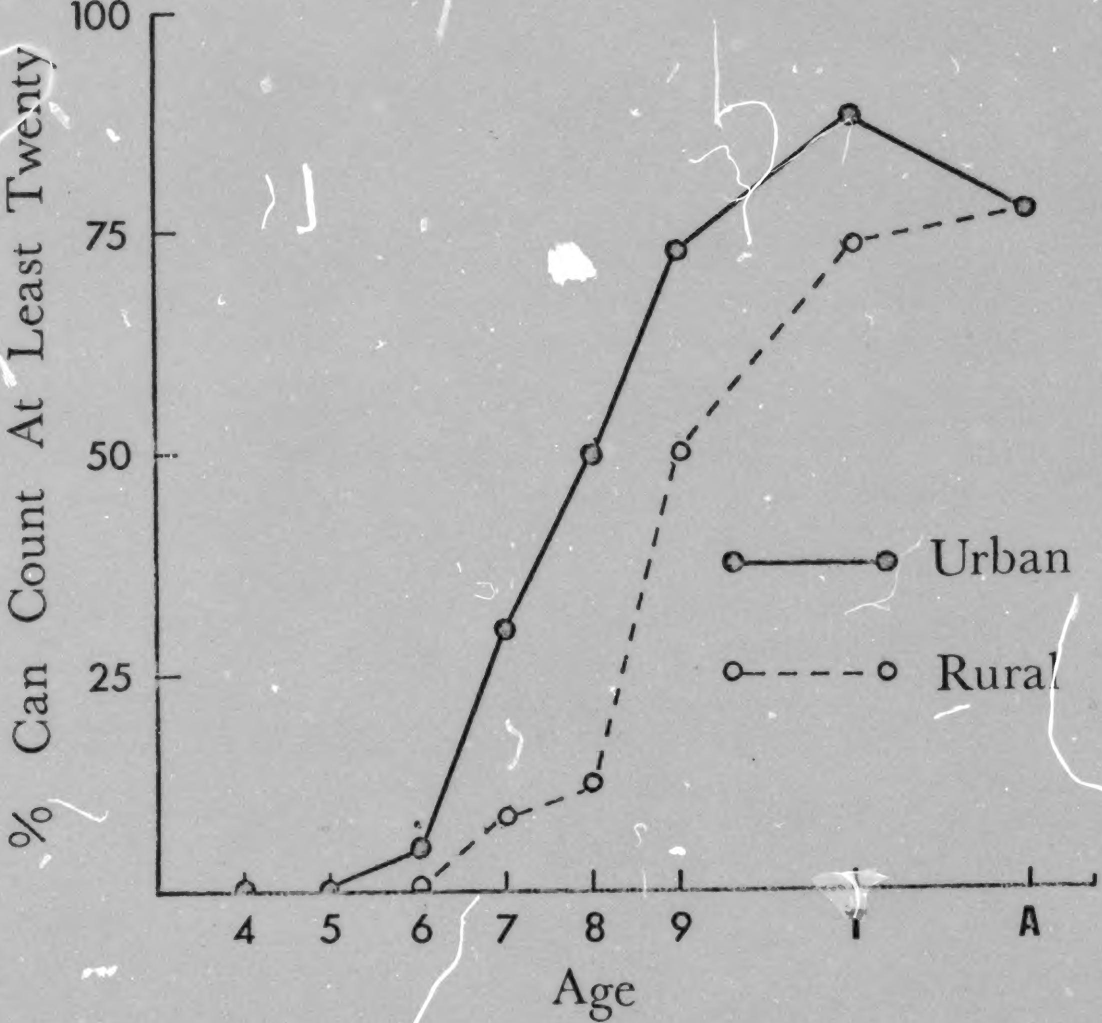
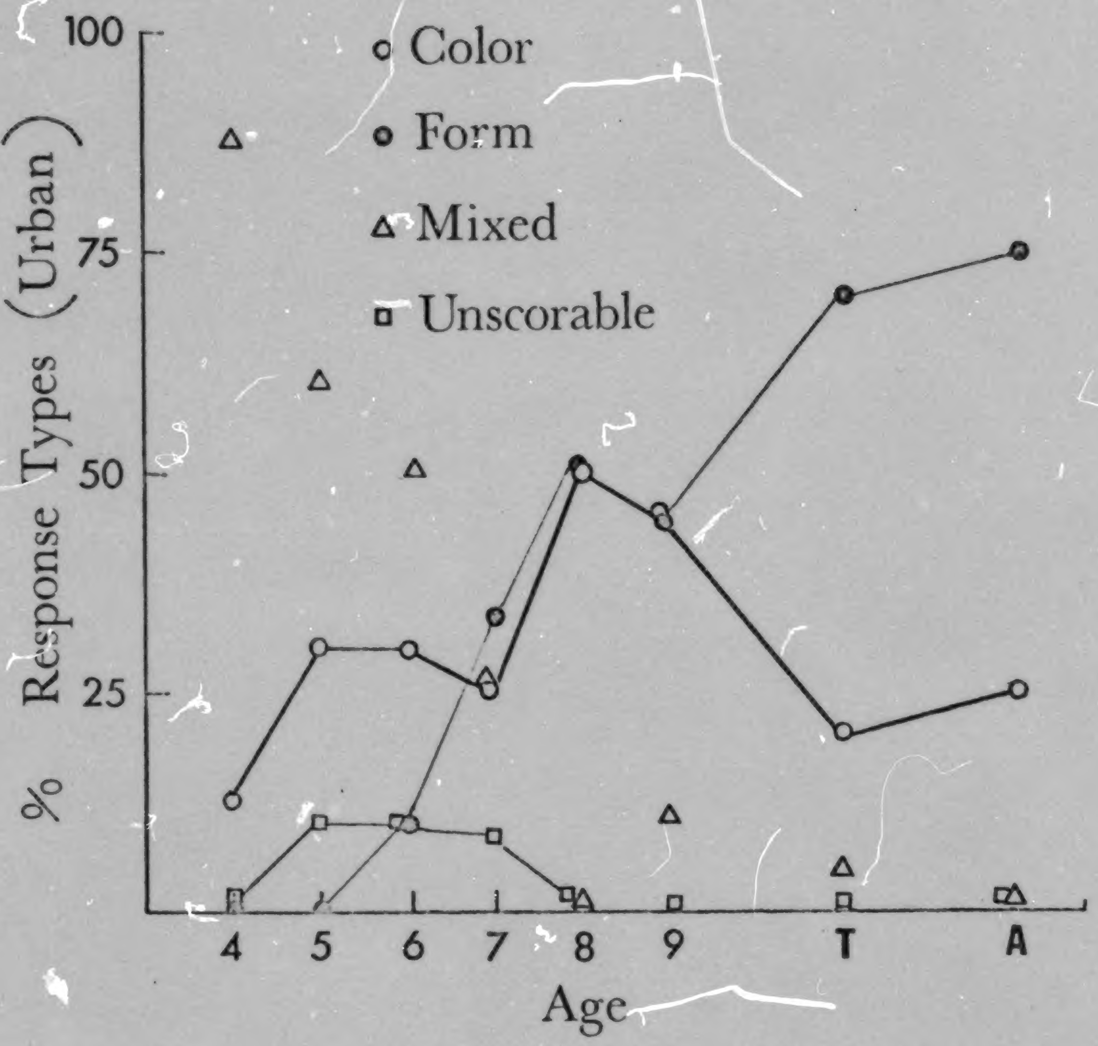


Figure 6 Percentage of children who can count to 20 or more, by age and sample. N urban and rural: as in Figure 3.



age
Figure 7 Percent/of urban subjects responding color-dominant, form-
by age.
dominant, mixed, and unscorable,/ N: 8, 10, 10, 12, 6, 18, 20, 8.

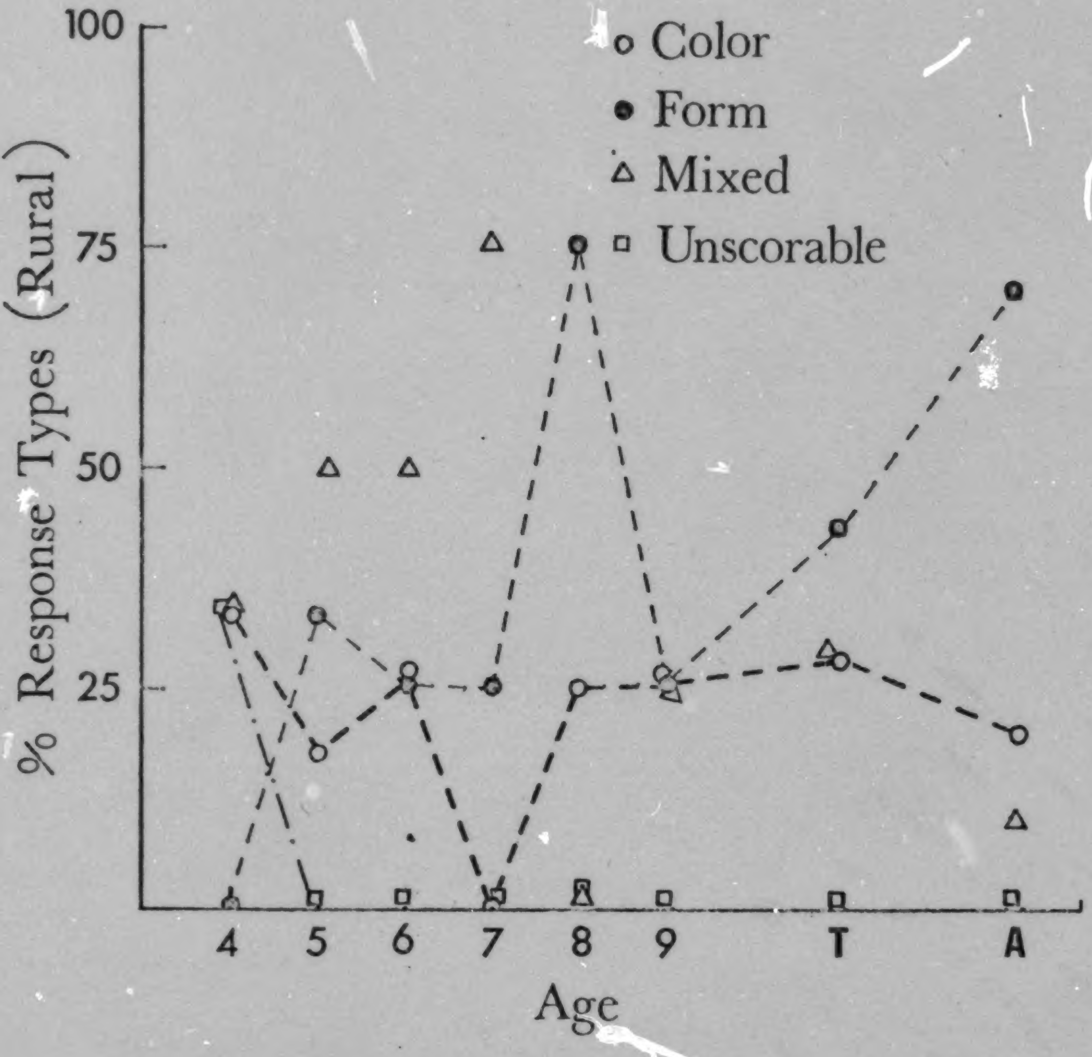


Figure 8 Percentage of rural subjects responding color-dominant, form-dominant, mixed, and unscorable, by age. N: 3, 6, 4, 4, 4, 4, 7, 10.

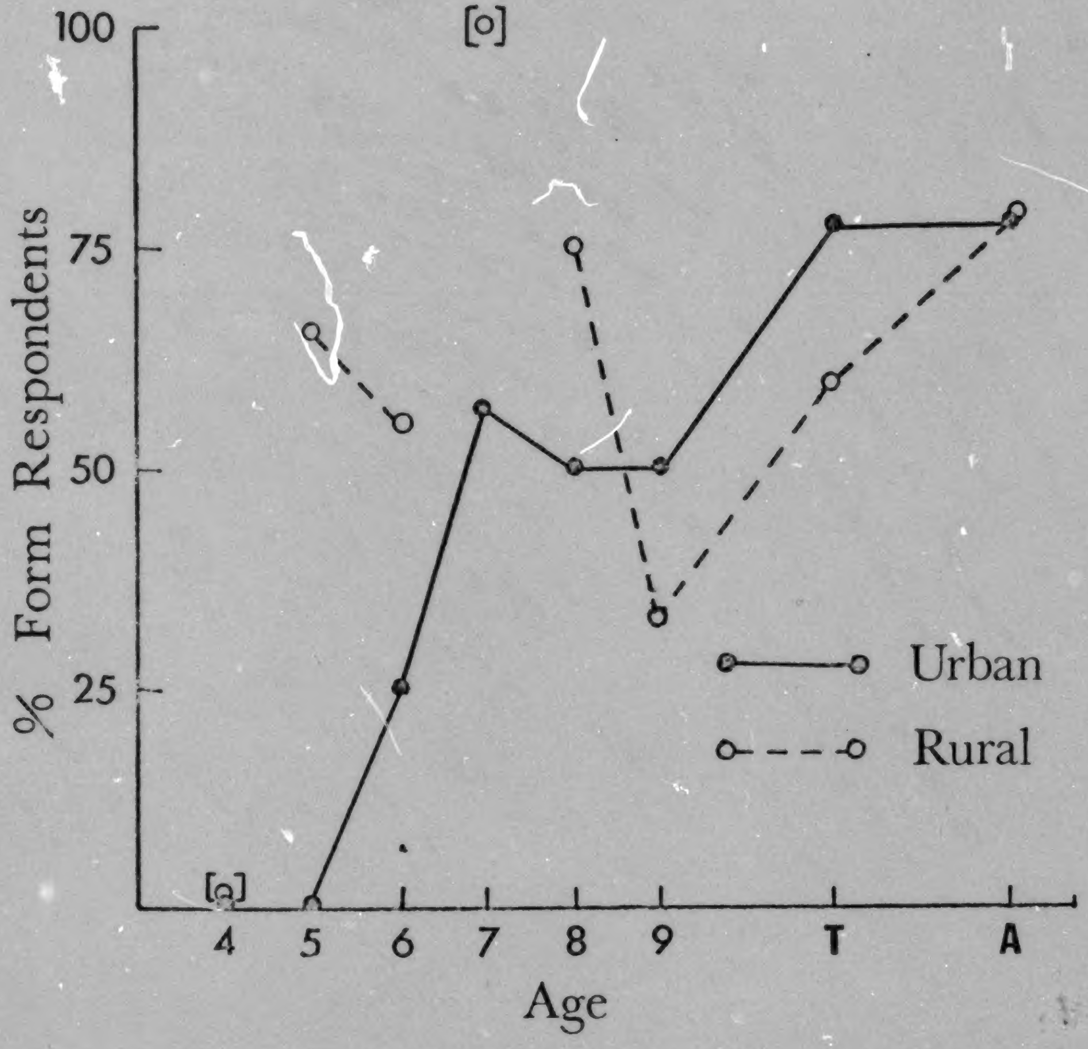


Figure 9 Percentage of consistant responders who responded form-dominant, by age and sample. N urban: 1, 4, 4, 7, 6, 16, 18, 8; rural: 1, 3, 2, 1, 4, 3, 5, 9.

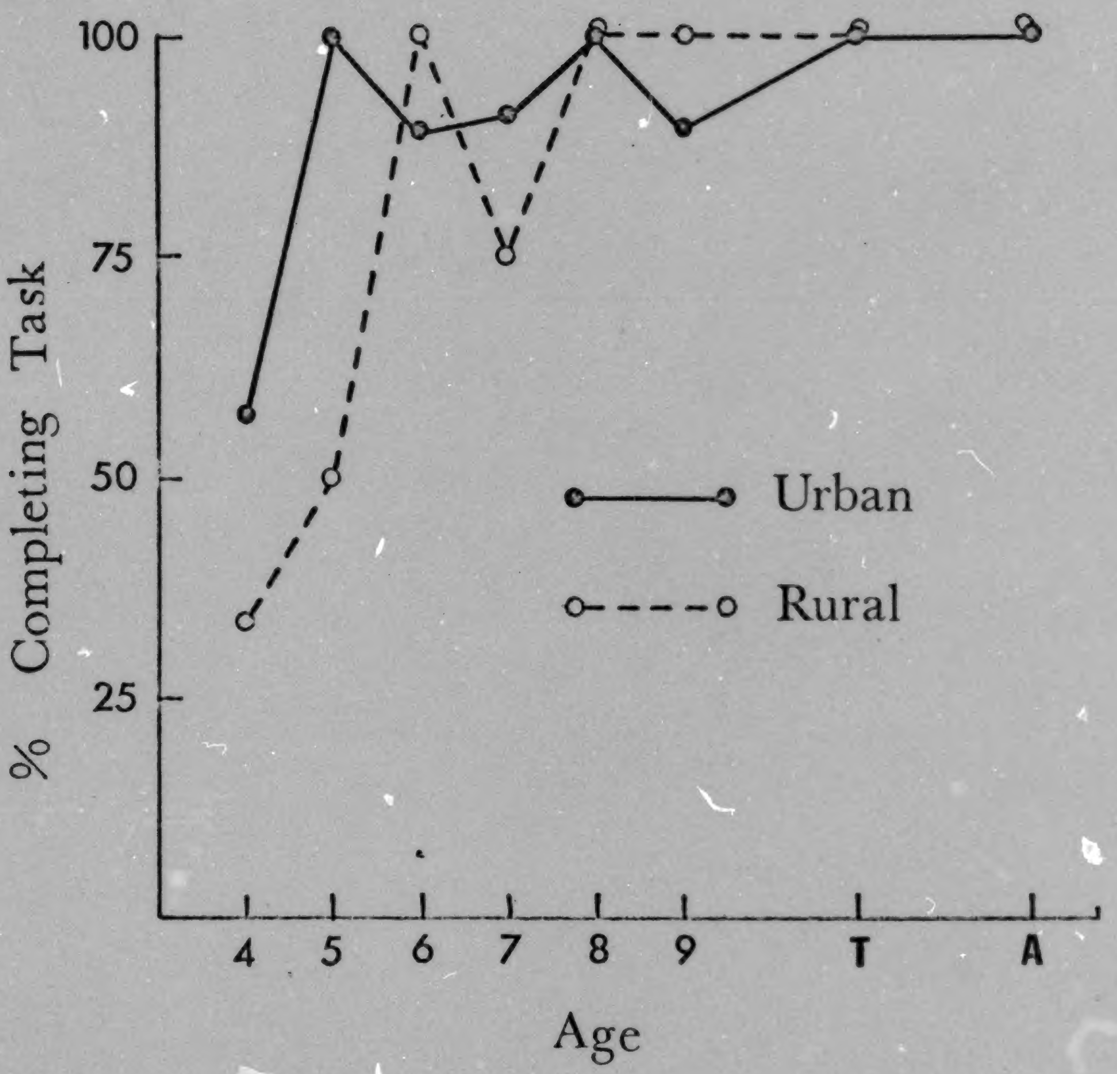


Figure 10 Percent of subjects completing the rotation task, by age and sample. N urban: 7, 9, 9, 11, 6, 9, 16, 8; rural: 3, 6, 4, 4, 4, 4, 7, 10.

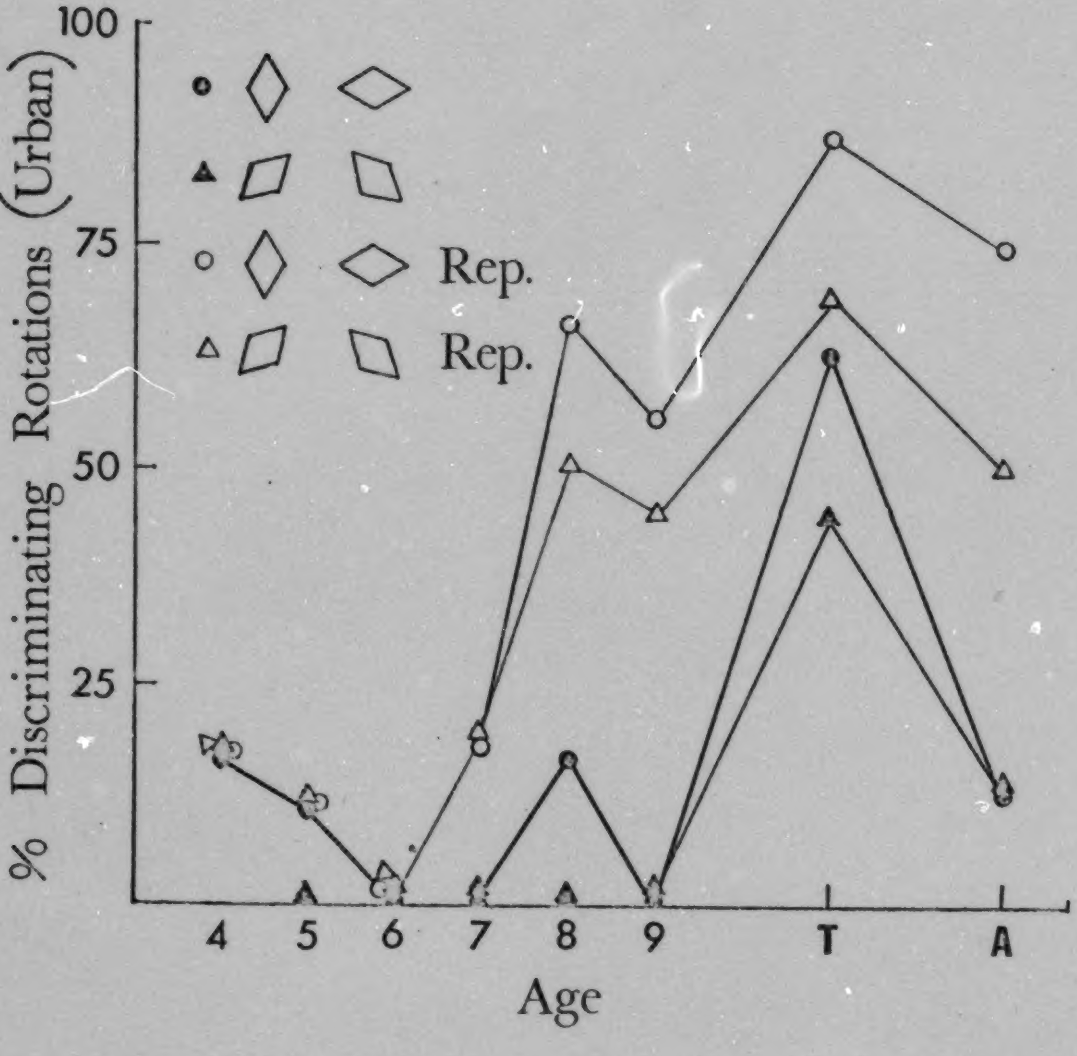


Figure 11 Percentage of urban subjects discriminating ~~rotations~~ rotated figures, by age and trial. N:6, 9, 9, 11, 6, 9, 16, 8.

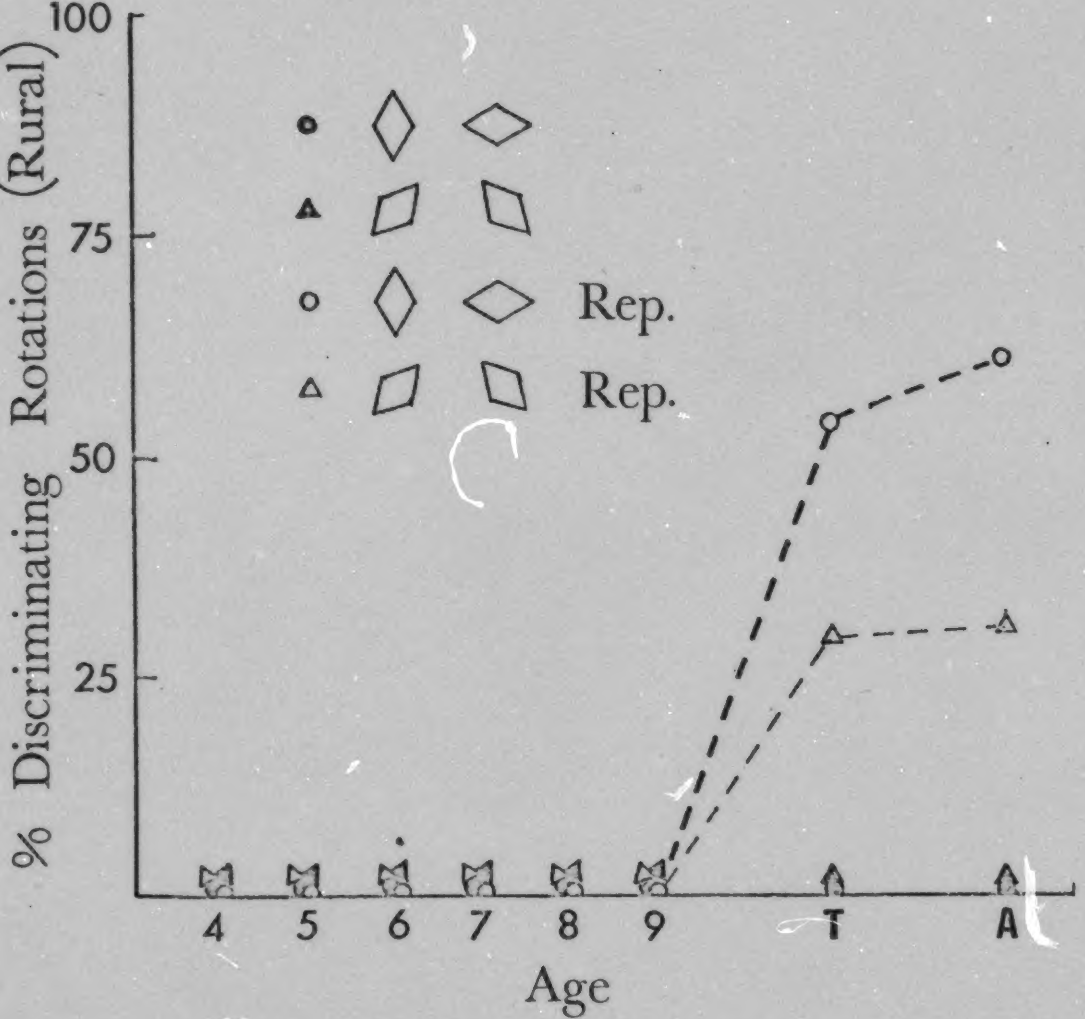


Figure 12 Percentage of rural subjects discriminating rotated figures, ~~rotations~~ by age and trial. N: 1, 4, 4, 3, 4, 4, 7, 10.

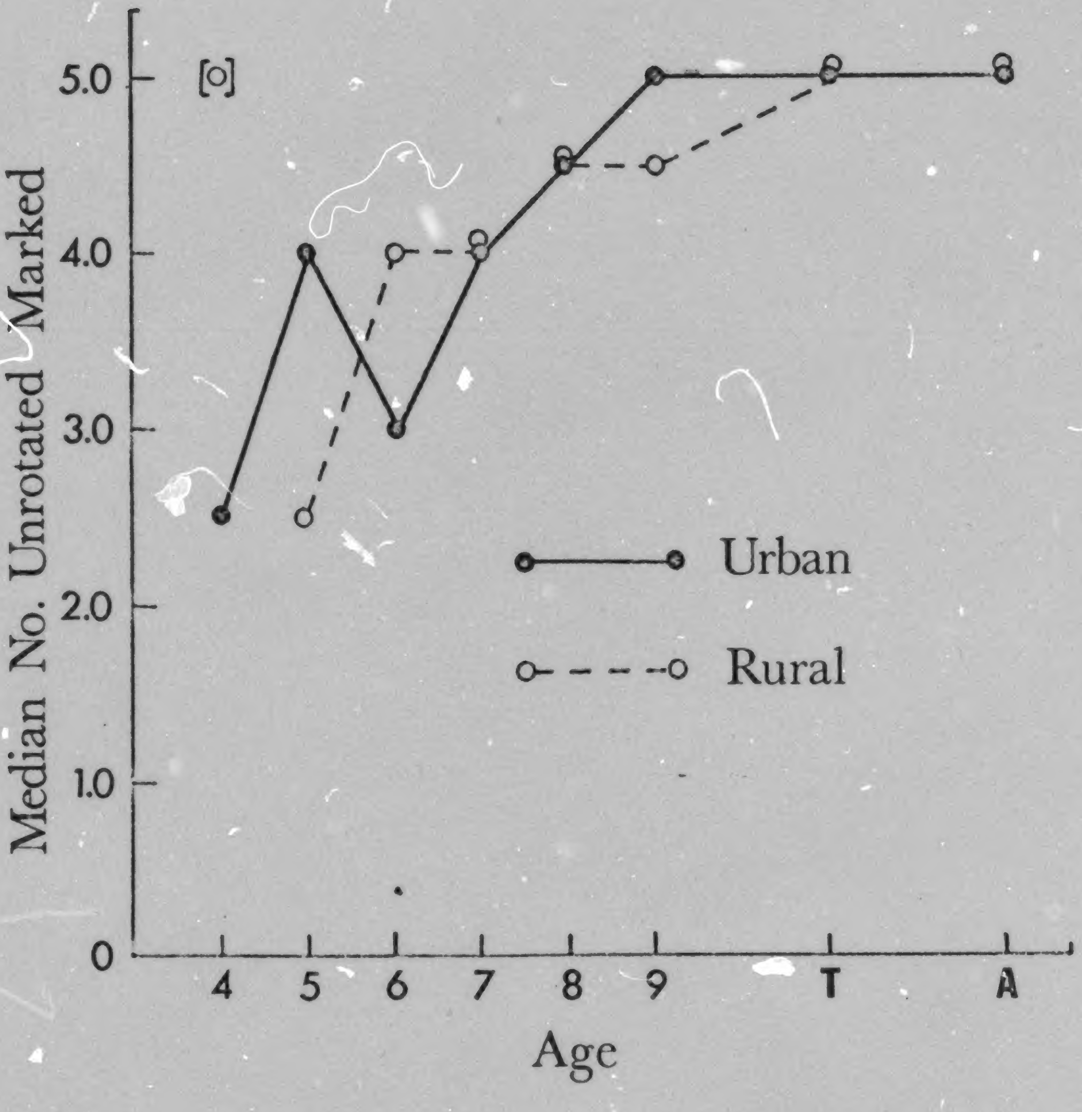


Figure 13 Median number of unrotated (correct) figures, by age and sample. N urban and rural: as in Figures 11 and 12.

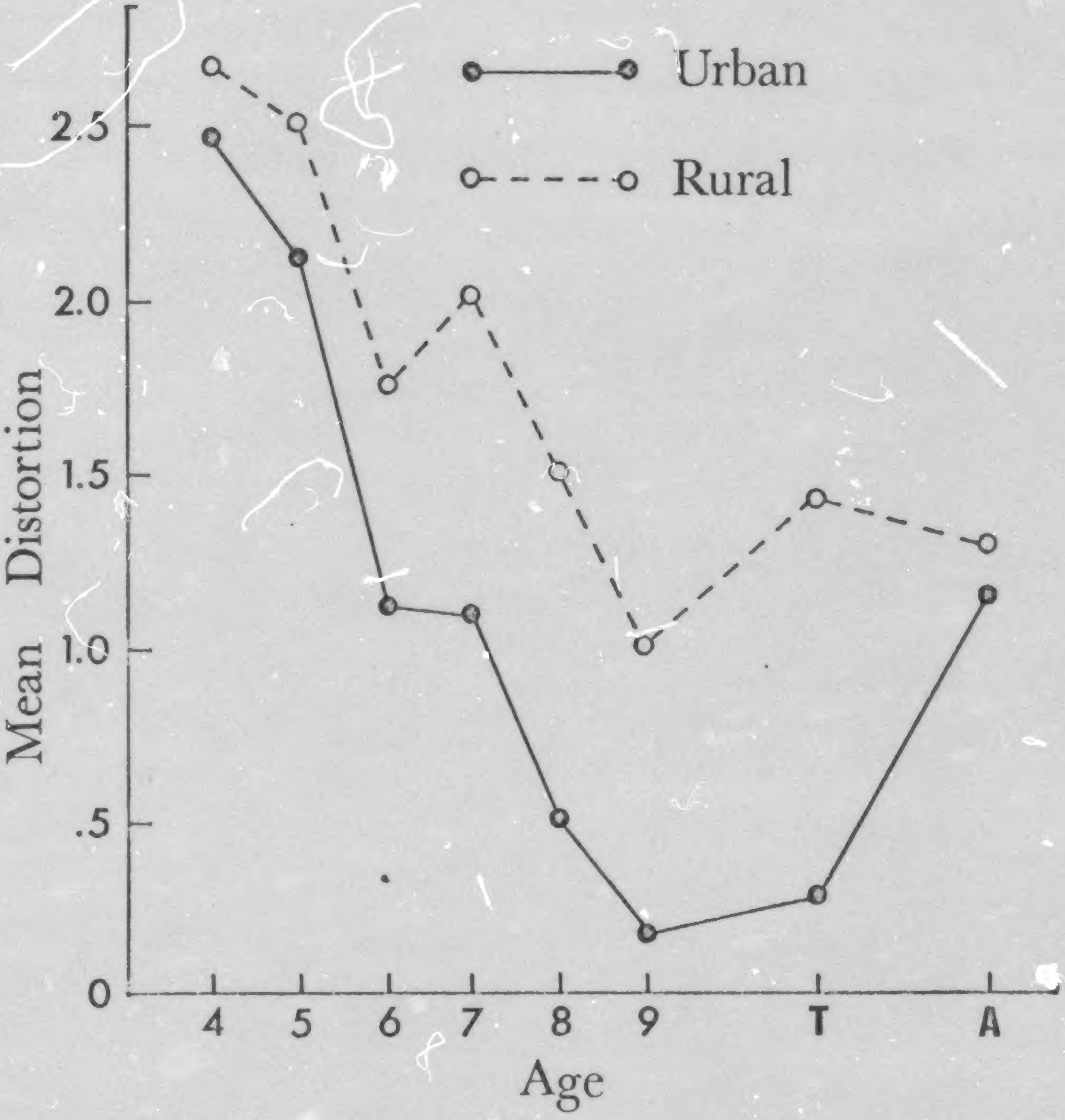


Figure 14 Mean sum of Bender Gestalt distortion scores, by age and sample. N urban: 7, 9, 9, 11, 6, 12, 18, 7; rural: 3, 6, 4, 4, 4, 4, 7, 10.

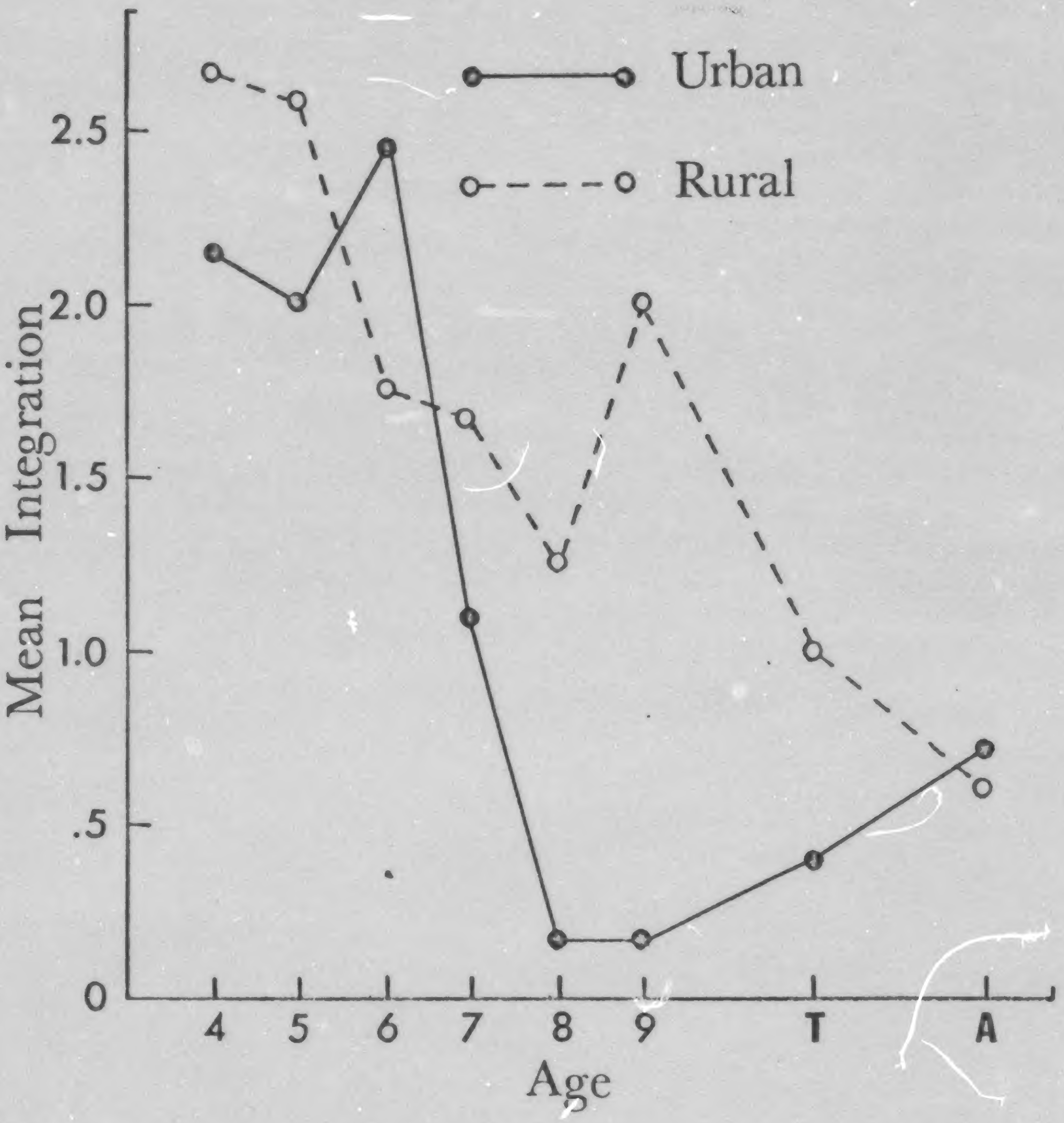


Figure 15 Mean sum of Bender Gestalt integration scores, by age and sample.

N urban: 7, 8, 9, 11, 6, 12, 18, 7; rural: 3, 5, 4, 3, 4, 4, 7, 10.

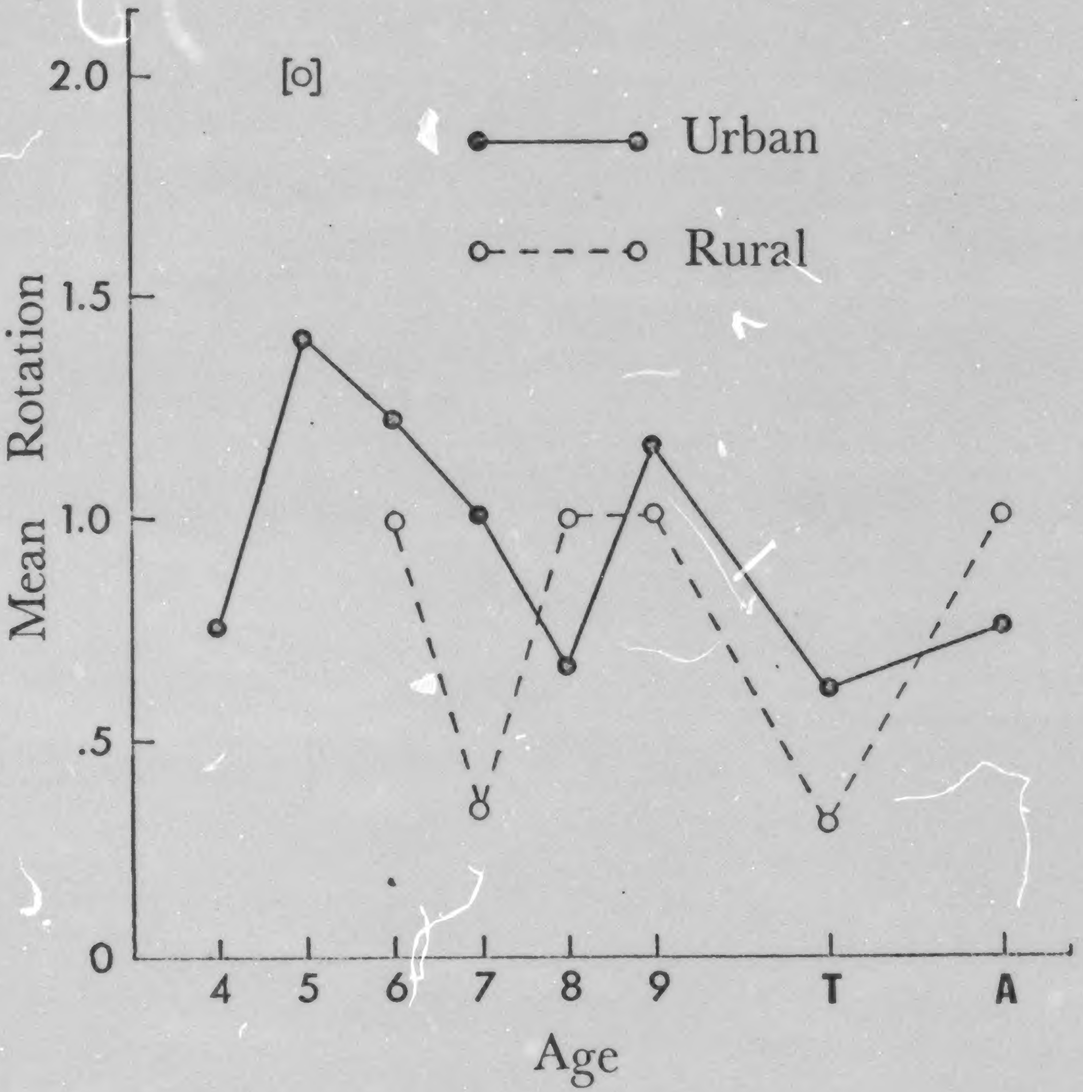


Figure 16 Mean sum of Bender Gestalt rotation scores, by age and sample, N urban: 4, 5, 9, 11, 6, 12, 18, 8; rural: 0, 1, 3, 3, 4, 3, 7, 10.

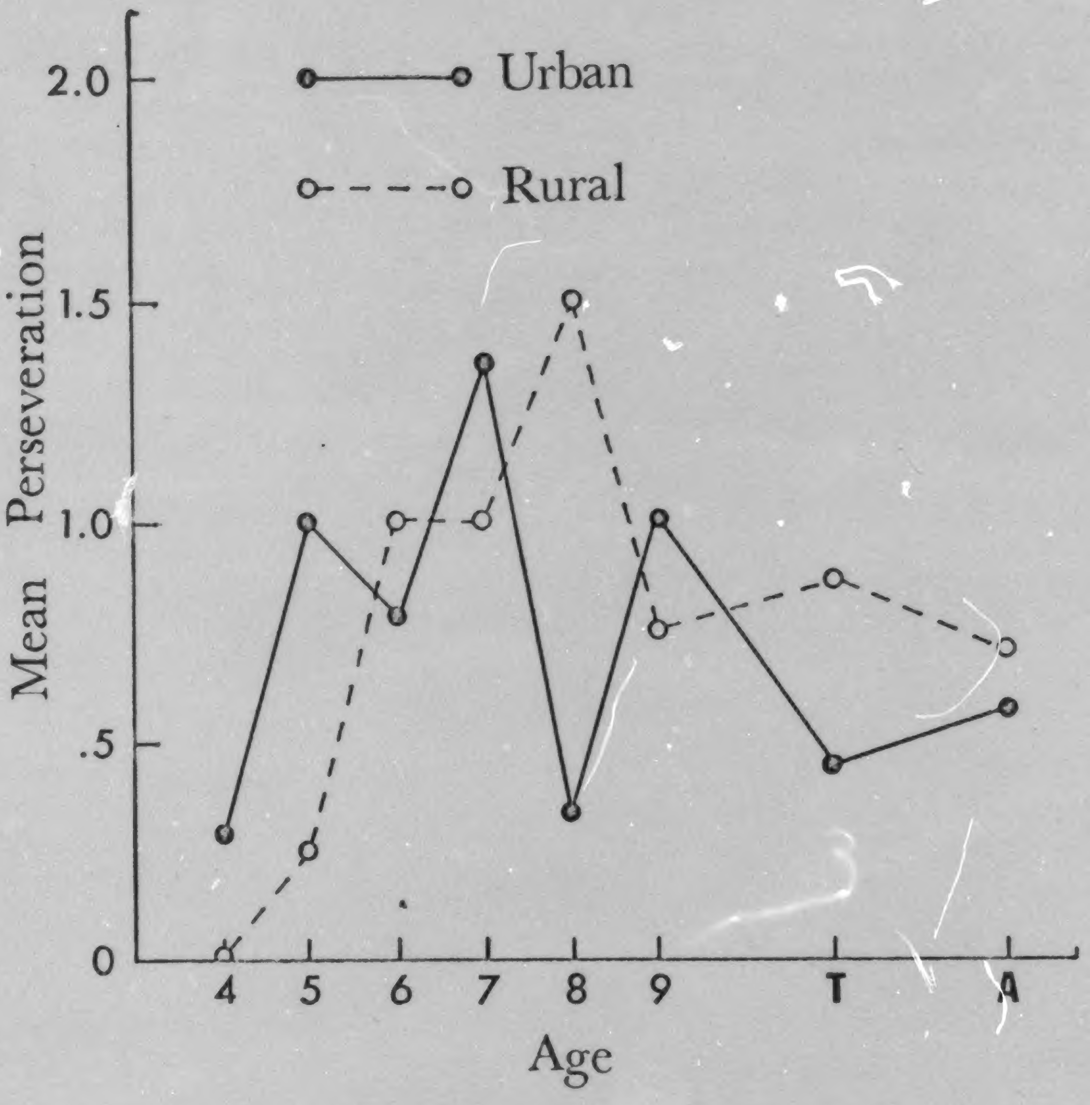


Figure 17 Mean sum of Bender Gestalt perseveration scores, by age and sample.

N urban: 7, 8, 9, 11, 6, 12, 18, 7; rural: 2, 4, 4, 4, 4, 4, 7, 10.

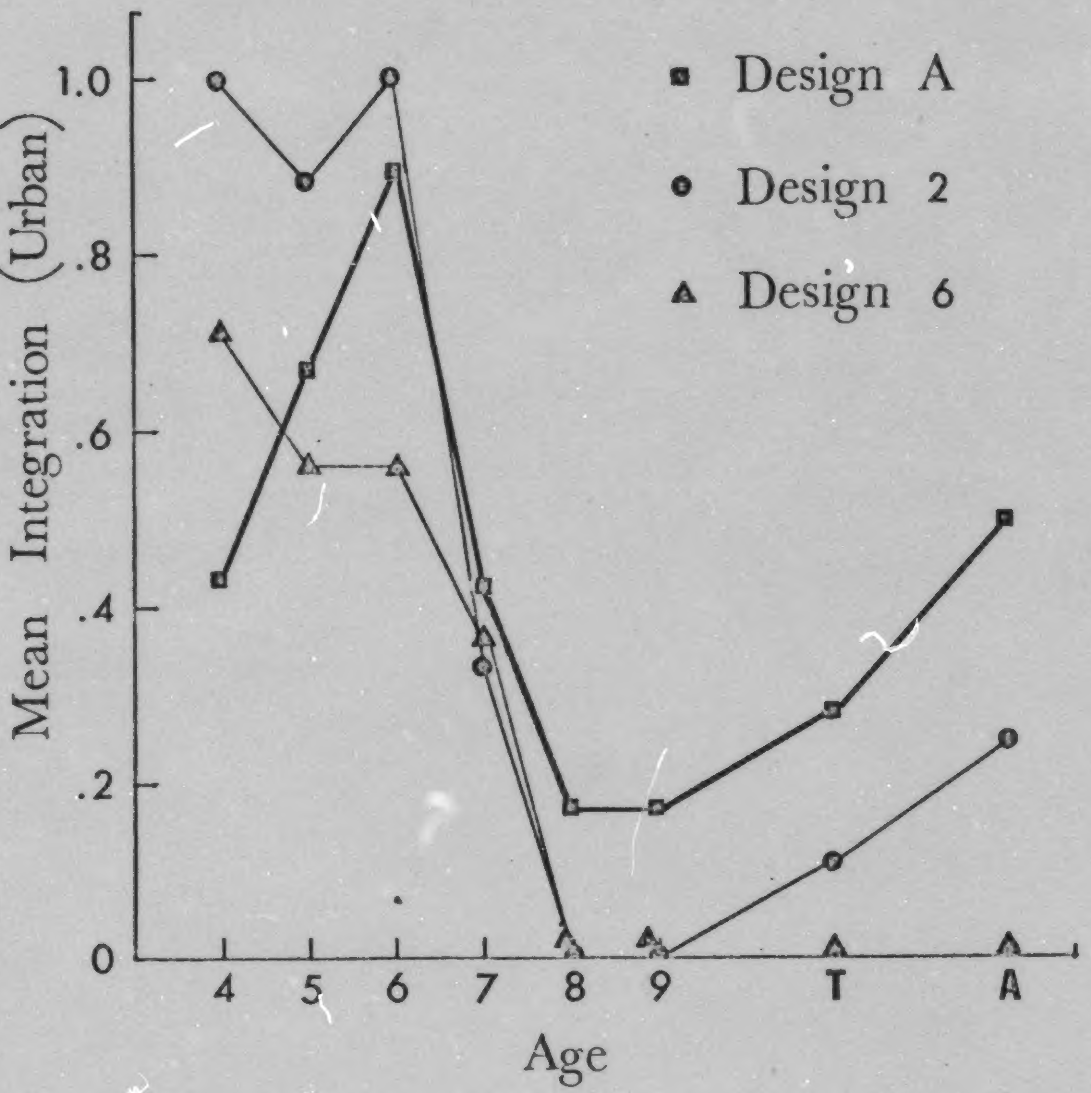


Figure 18 Mean Bender Gestalt integration scores, urban subjects, by age and design. N: as in Figure 15.

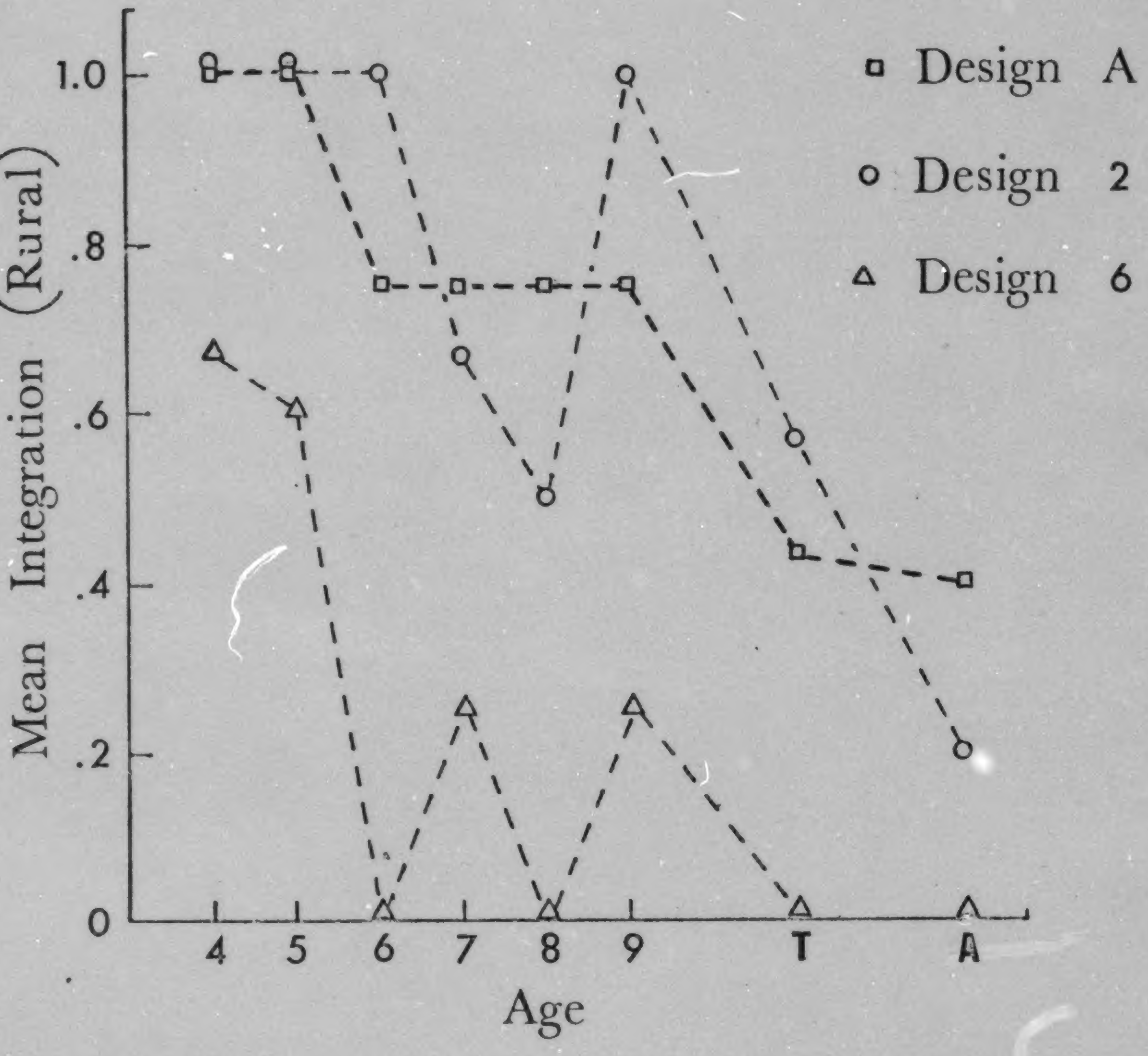


Figure 19 Mean Bender Gestalt integration scores, rural subjects, by ag and design. N: as in Figure 15.

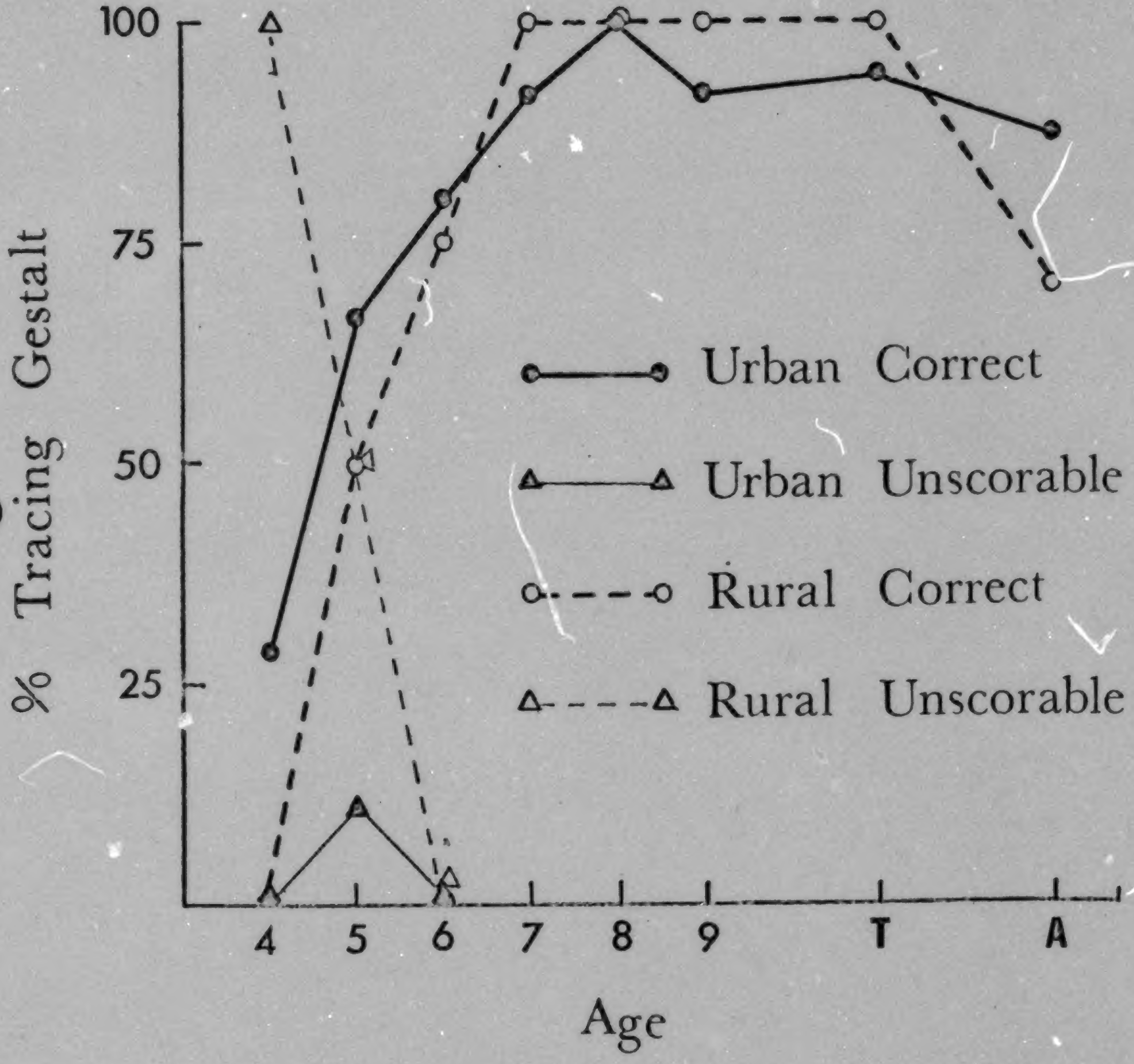


Figure 20 Percentage of subjects who traced Bender Gestalt design A as a Gestalt, or as unscorable, by age and sample. N urban: 7, 9, 10, 12, 6, 12, 18, 8; rural: 3, 6, 4, 4, 4, 4, 7, 10.

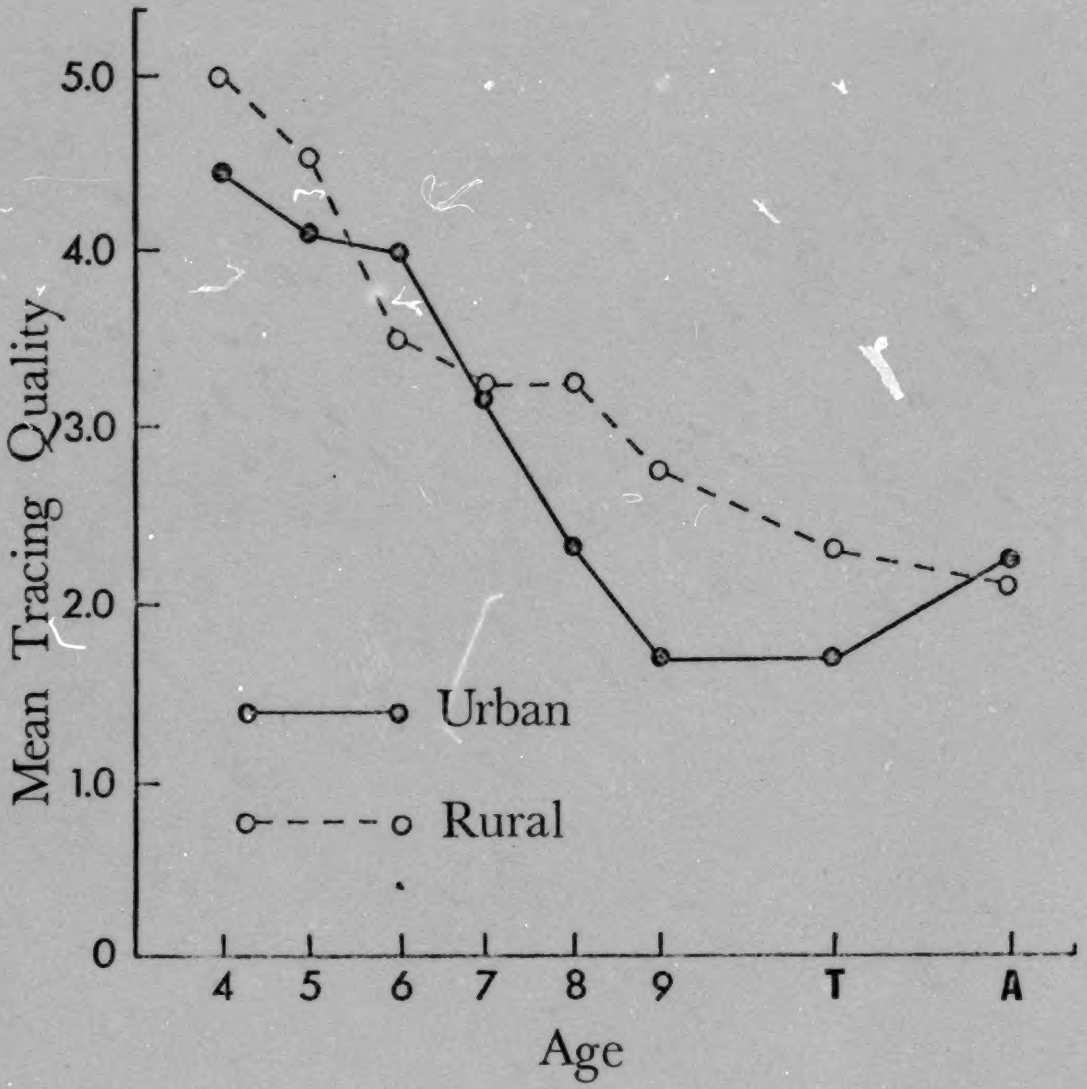


Figure 21 Mean quality rating for tracing Bender Gestalt design A, by age and sample. N urban and rural: as in Figure 20.

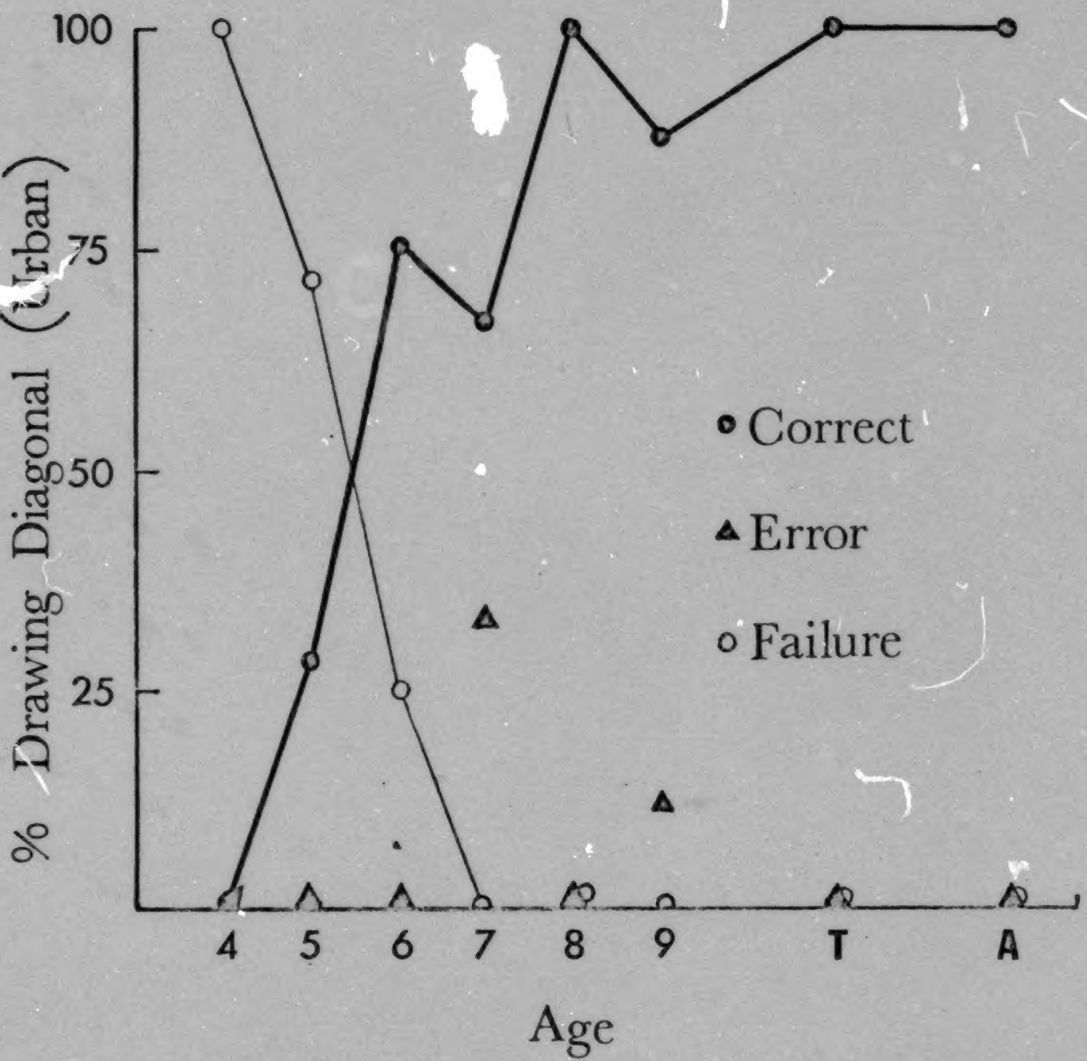


Figure 22 Percentage of/subjects drawing diagonal correctly, with an error on the end, and complete failure, by age. N: 5, 7, 8, 6, 6, 8, 12, 9.

urban

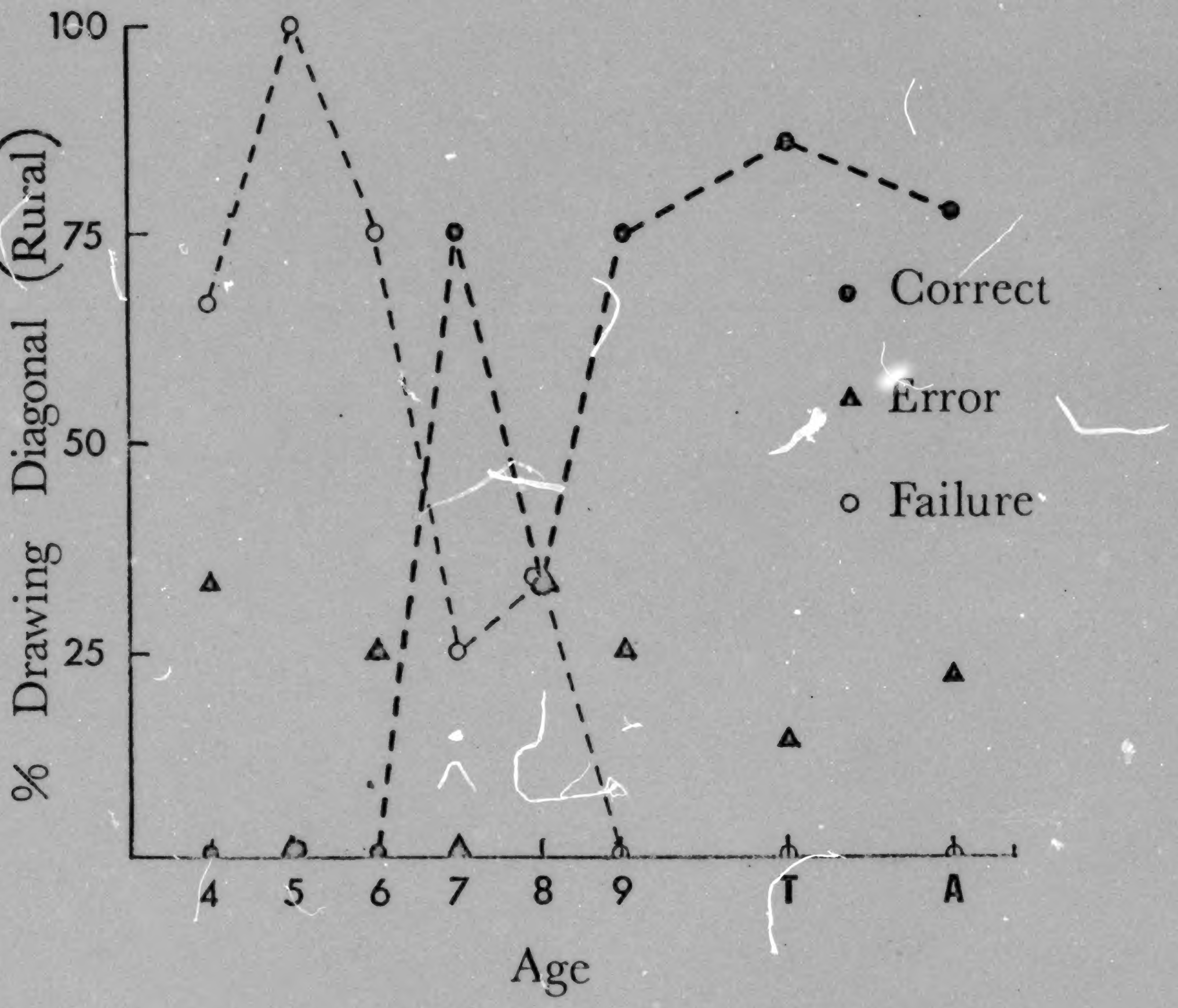


Figure 23 Percentage of ruralsubjects drawing diagonal correctly, with an error on the end, and complete failure, by age. N: 3, 6, 4, 4, 3, 4, 7, 9.

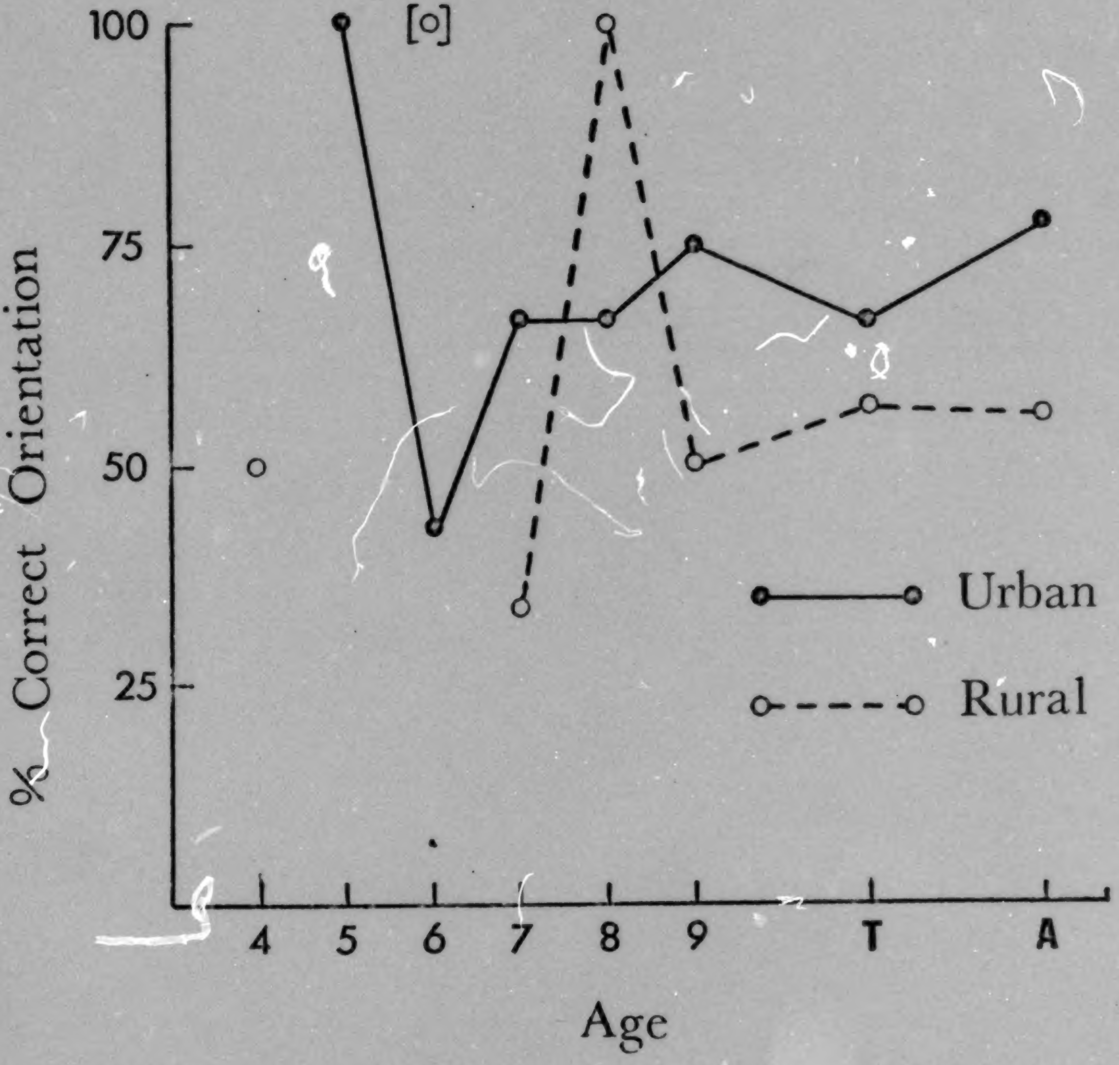


Figure 24. Percentage of subjects drawing diagonal with correct orientation, by age and sample. N urban: 0, 2, 7, 6, 6, 8, 12, 9; rural: 2, 0, 1, 3, 2, 4, 7, 9.

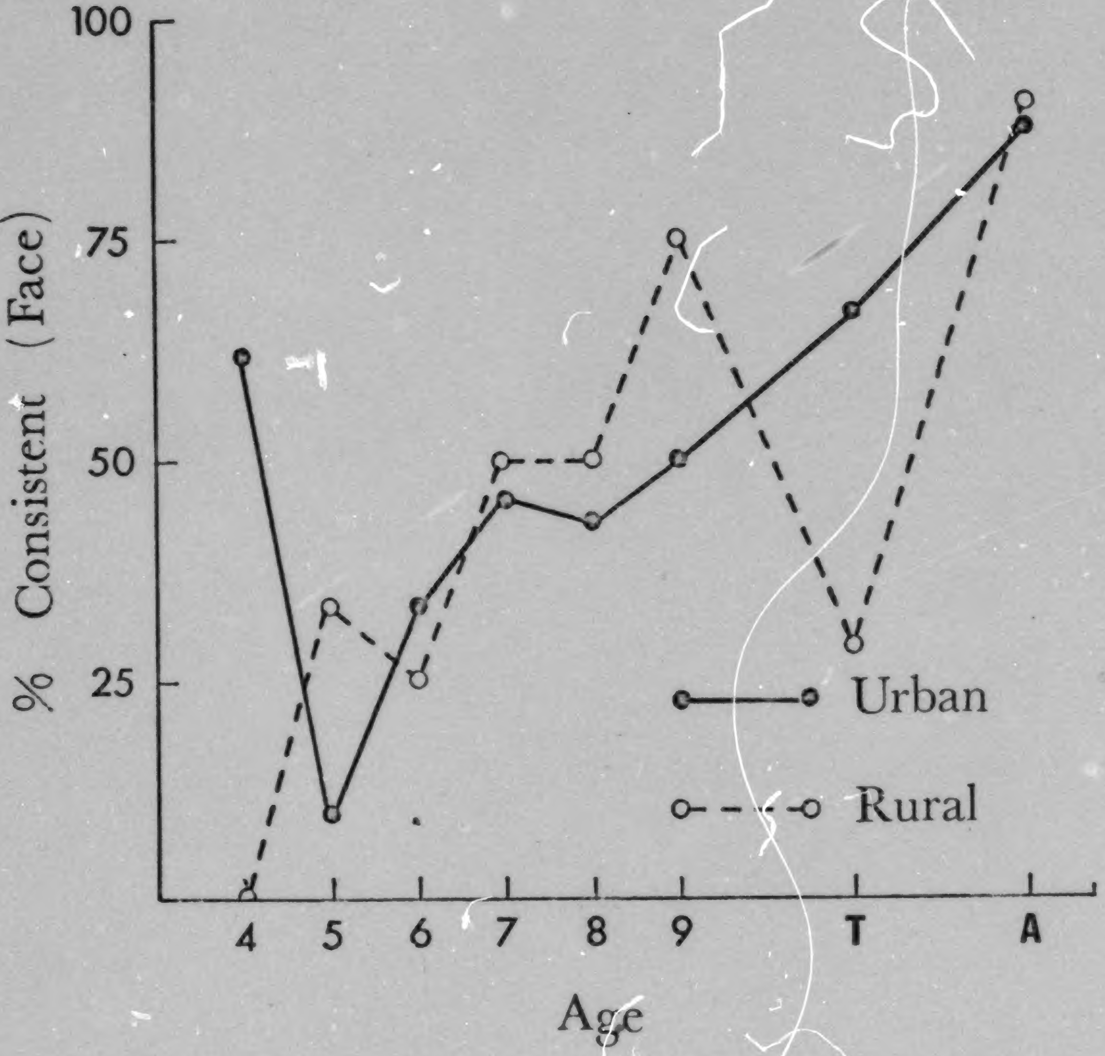


Figure 25 Percentage of subjects responding to doll facing them consistant with answer for self, by age and sample. N urban: 6, 10, 9, 11, 7, 8, 18, 8; rural: 3, 6, 4, 4, 4, 4, 7, 10.

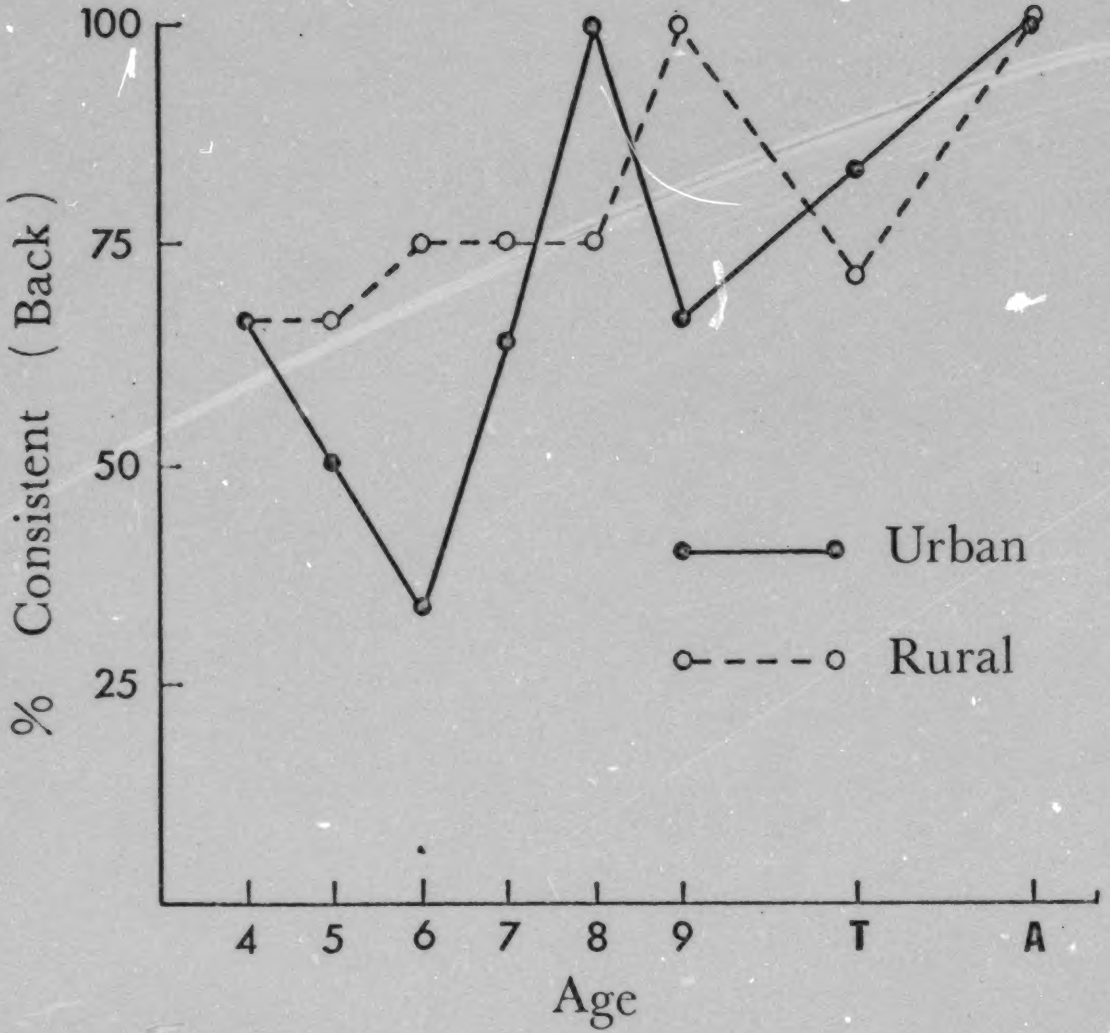


Figure 26 Percentage of subjects responding to doll with back to them consistant with answer for self, by age and sample. N urban: 6, 10, 9, 11, 7, 9, 18, 8; rural: as in figure 25.

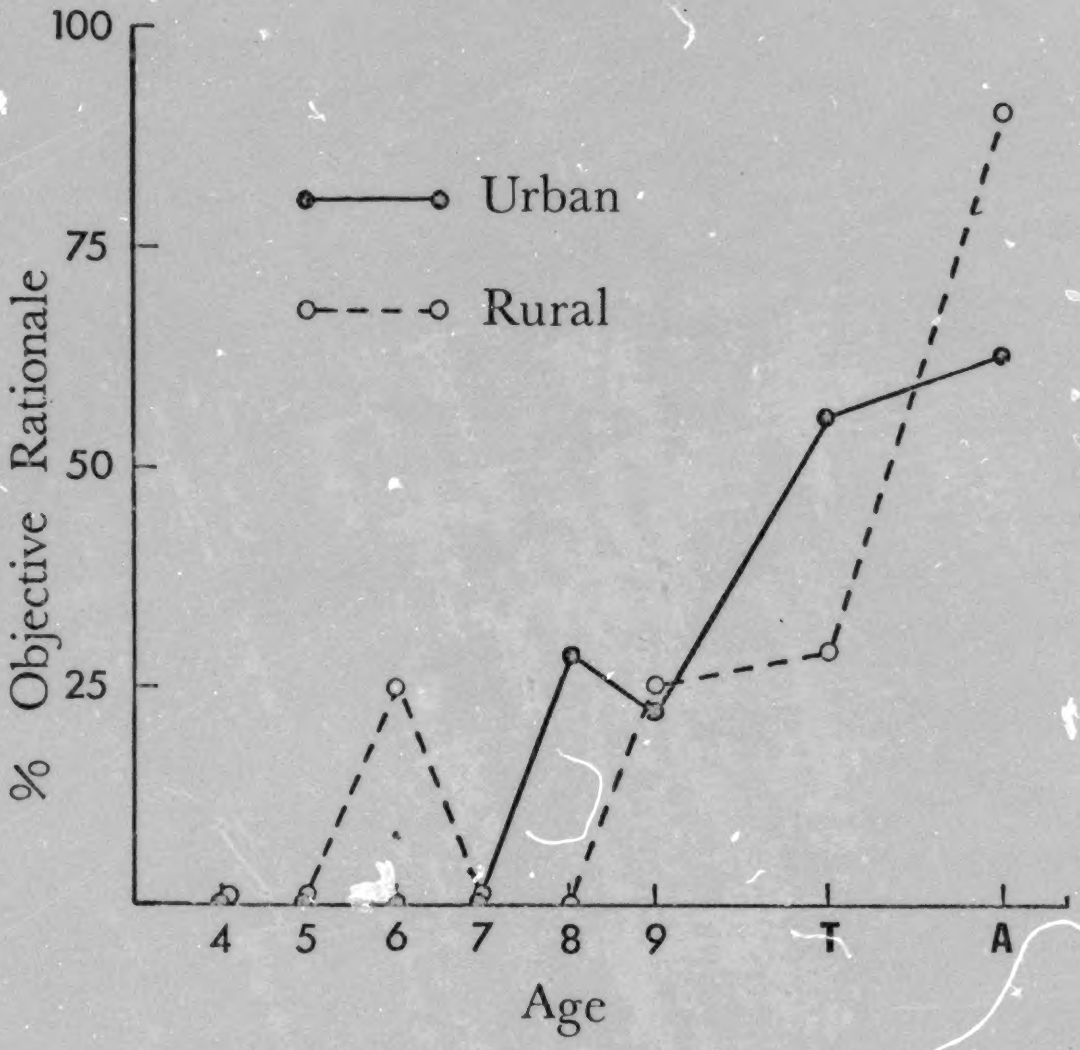


Figure 27 Percentage of subjects giving objective rationale for answers to left-right questions, by age and sample. N urban: 6, 9, 9, 11, 7, 9,18,8; rural: as in figure 25.

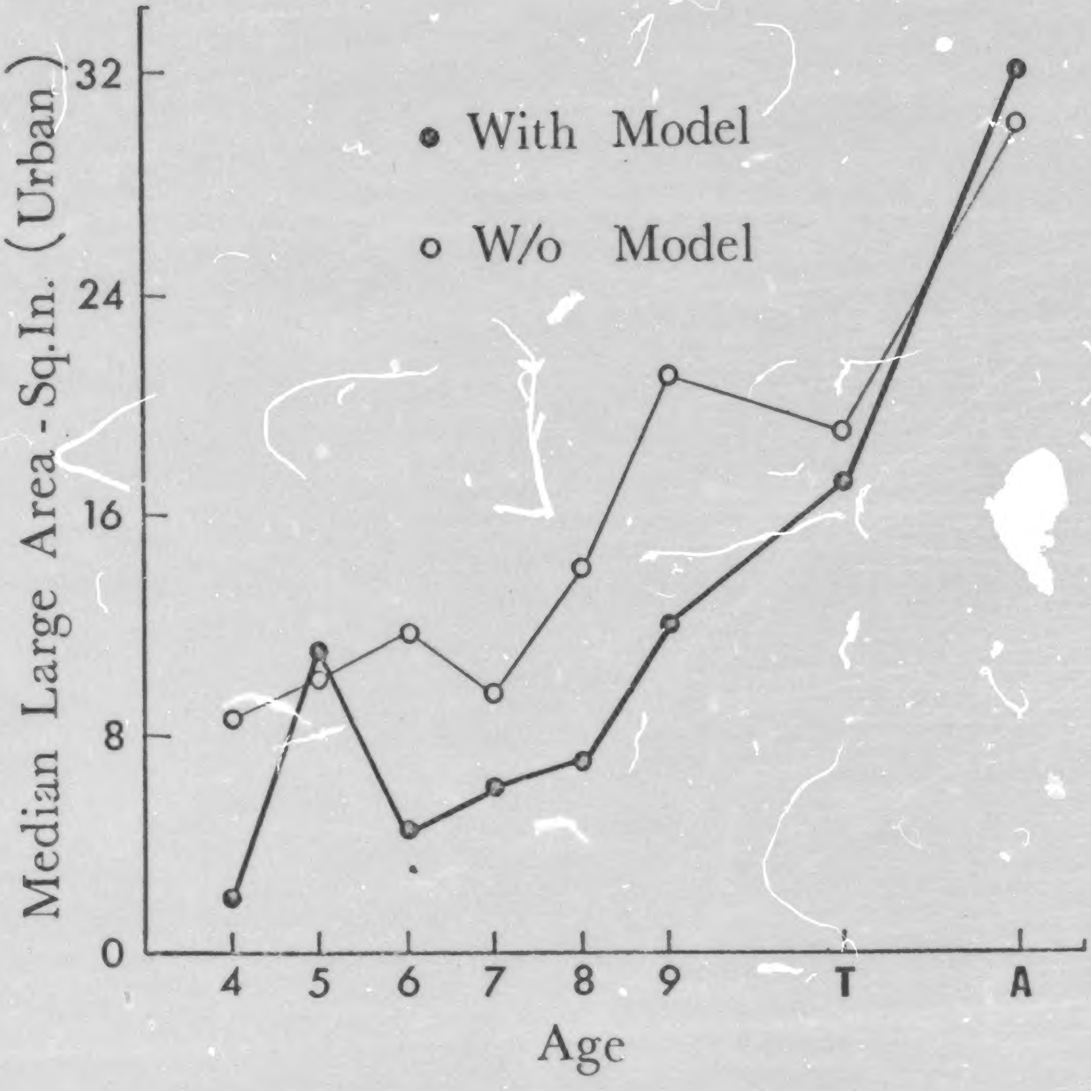


Figure 28 Median area of large square, with and without model present, urban subjects, by age. N: with: 12, 17, 18, 23, 16, 26, 38, 16; without: 12,15, 18, 18, 14, 15, 28, 9.

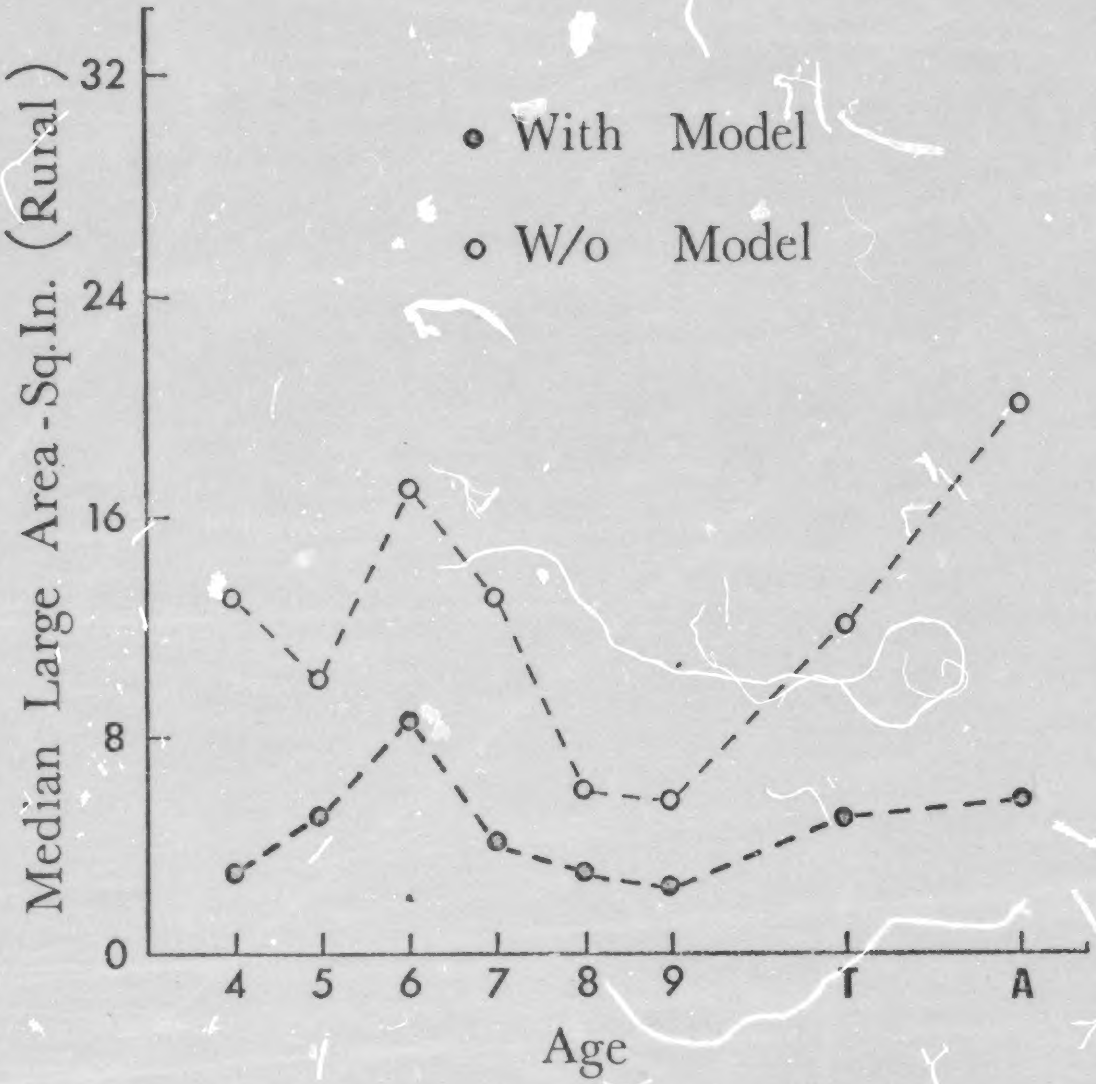


Figure 29 Median area of large square, with and without model present, rural subjects, by age. N with: 5, 11, 10, 11, 7, 8, 15, 20; without: 4, 11, 10, 11, 7, 8, 15, 19.

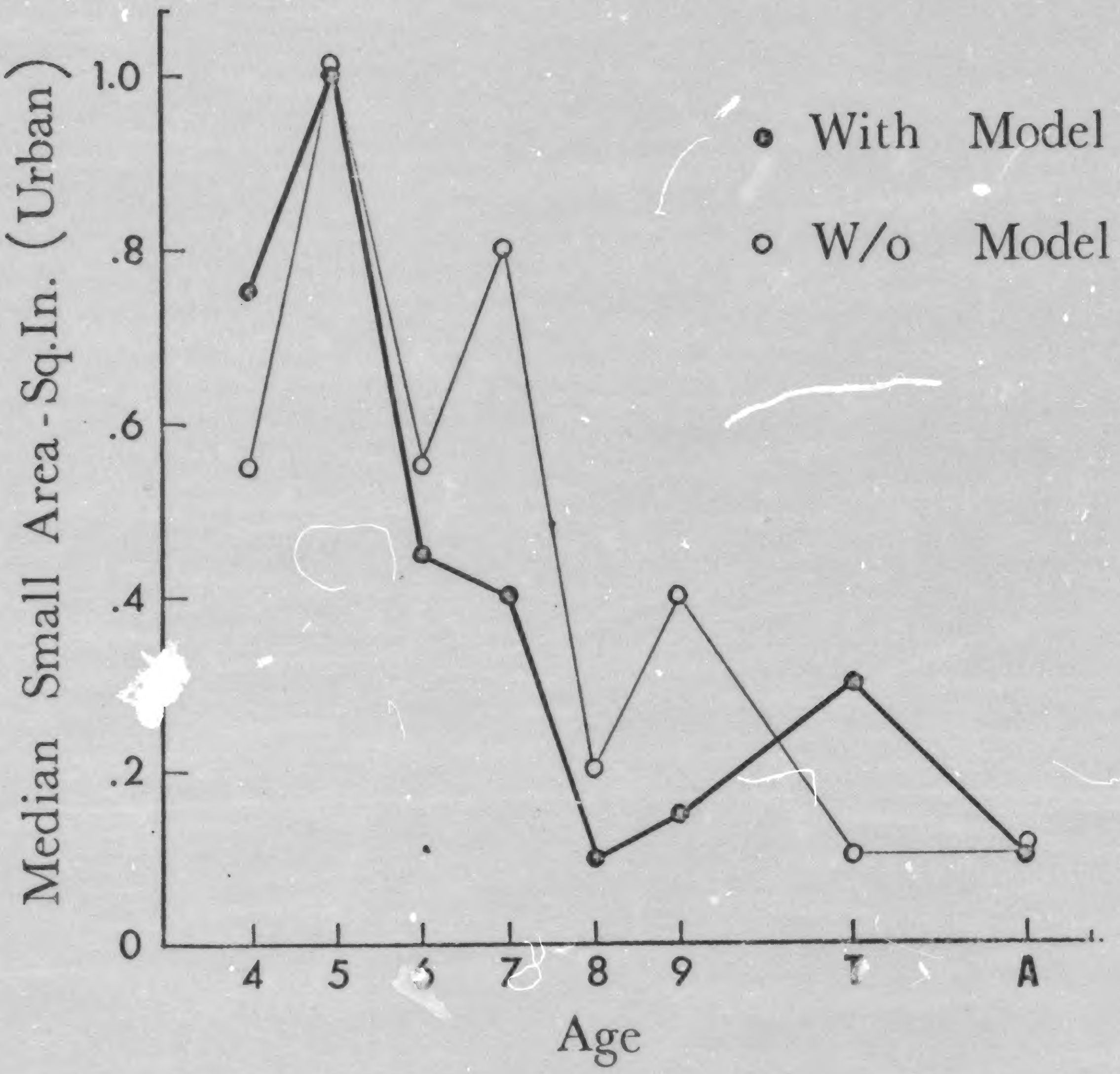


Figure 30 Median area of small square, with and without model present, urbansubjects, by age. N with and without, as in figure 28.

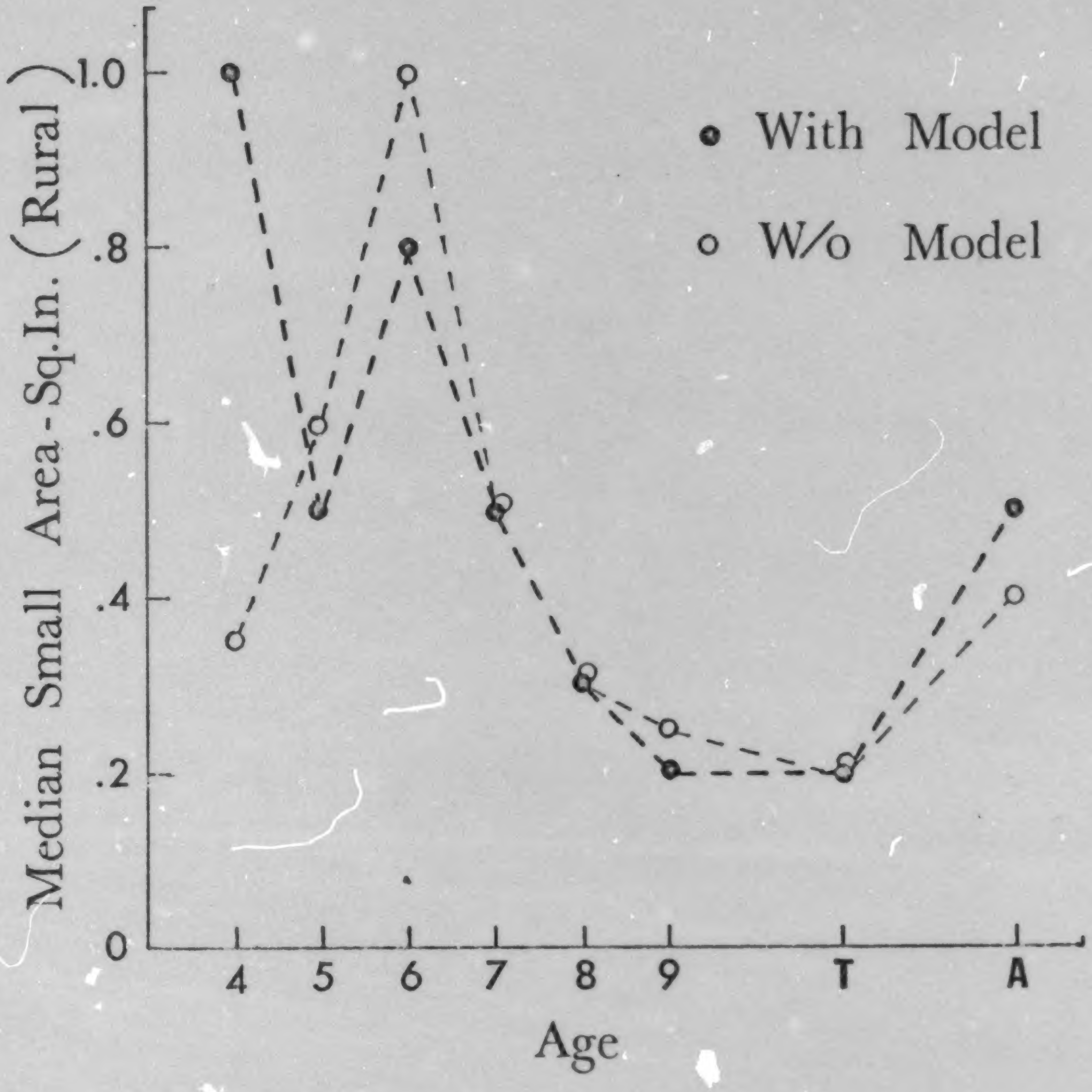


Figure 31 Median area of small square, with and without model present, rural subjects, by age. N with and without, as in figure 29.

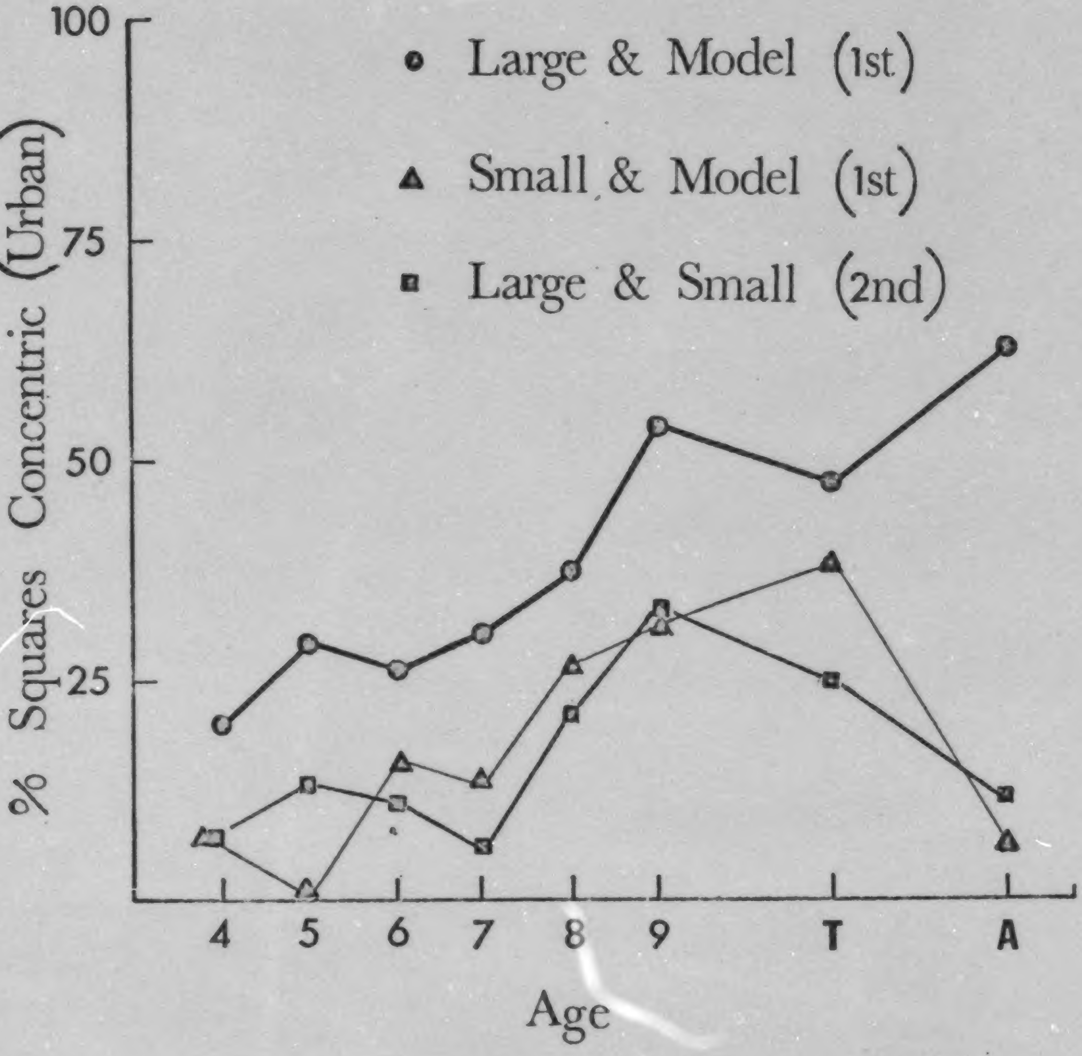


Figure 32 Percentage of urban subjects who draw squares concentric, bytrial and age: N : as in figure 28.

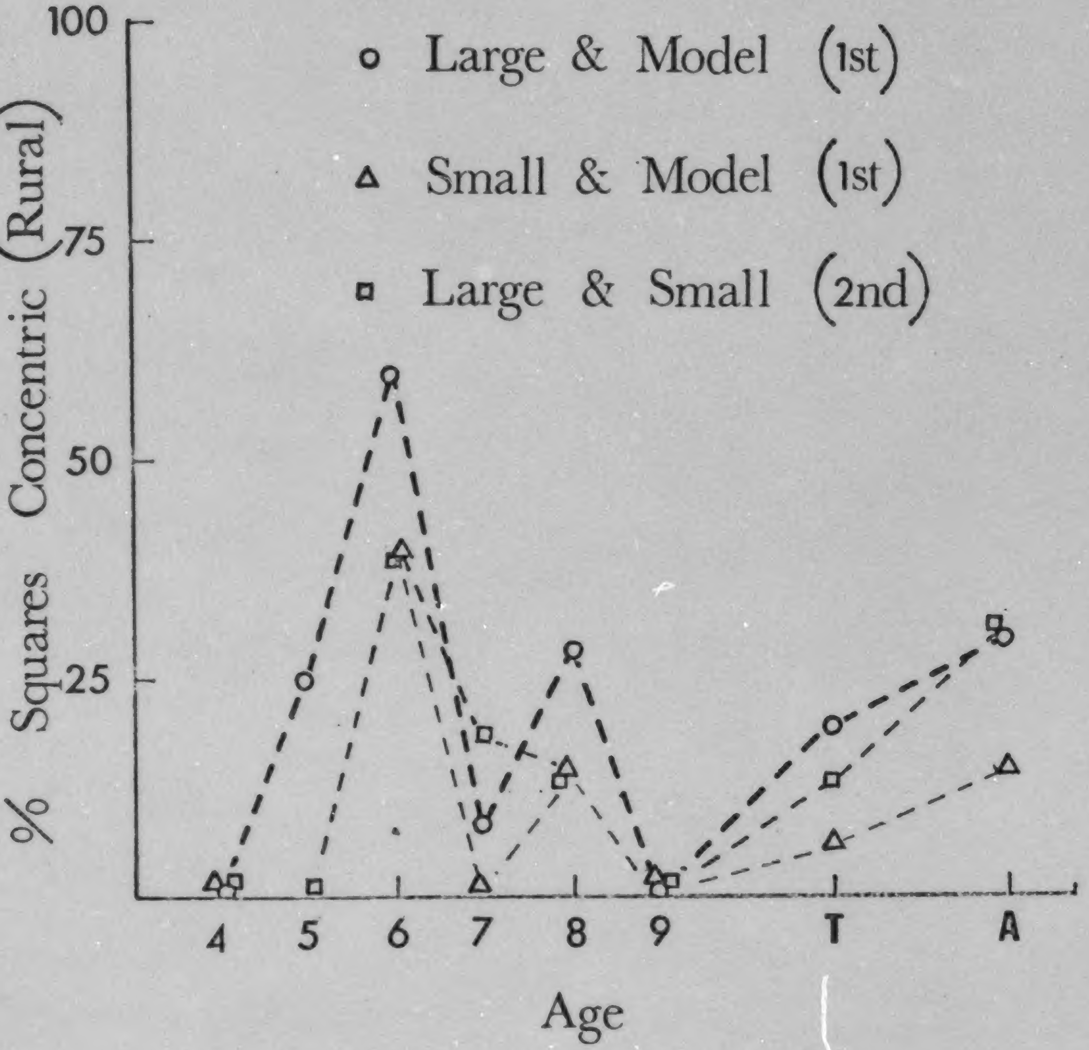


Figure 33 Percentage of rural subjects who drew squares concentric, by trial and age. N: as in figure 29.

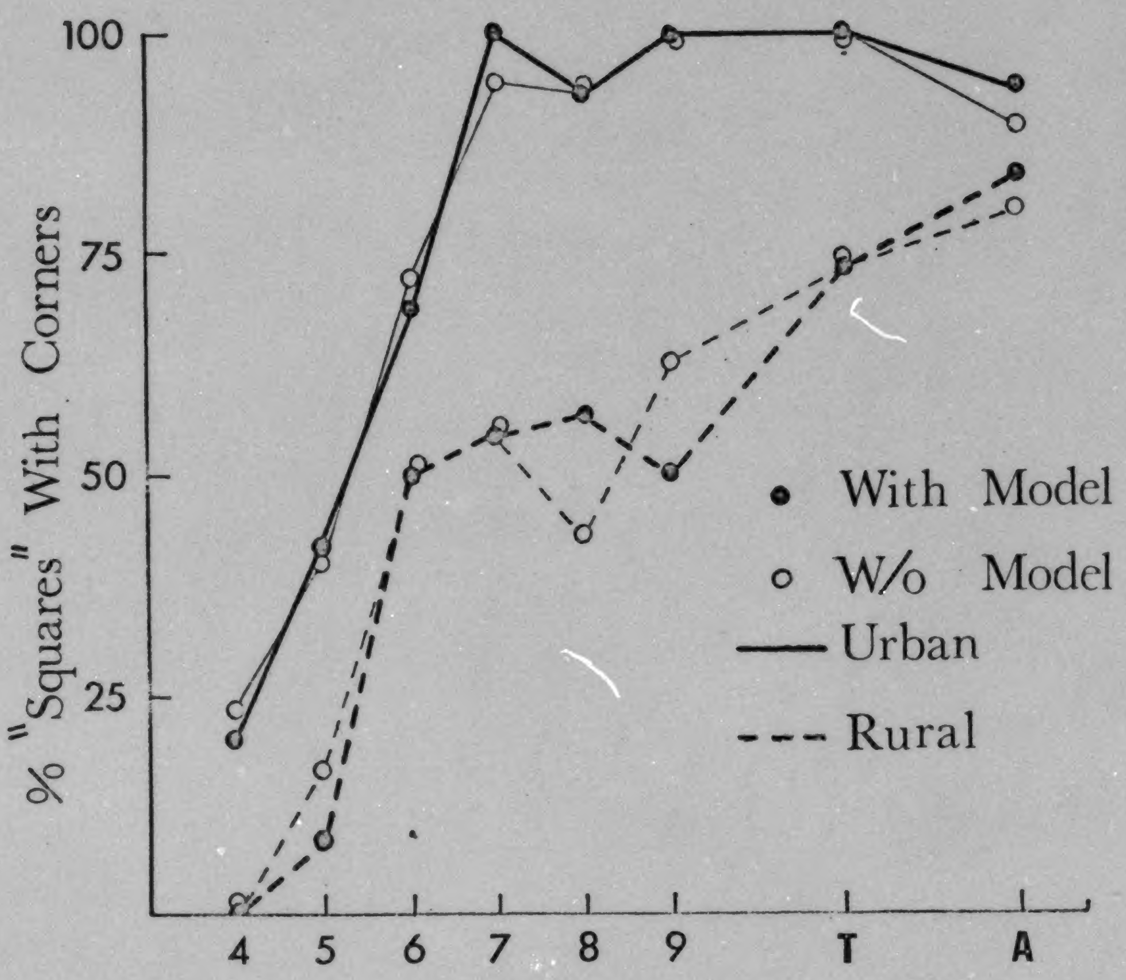


Figure 34 Percentage of subjects who drew large "square" with corners, by trial, age, and sample. N: as in figures 28 and 29.

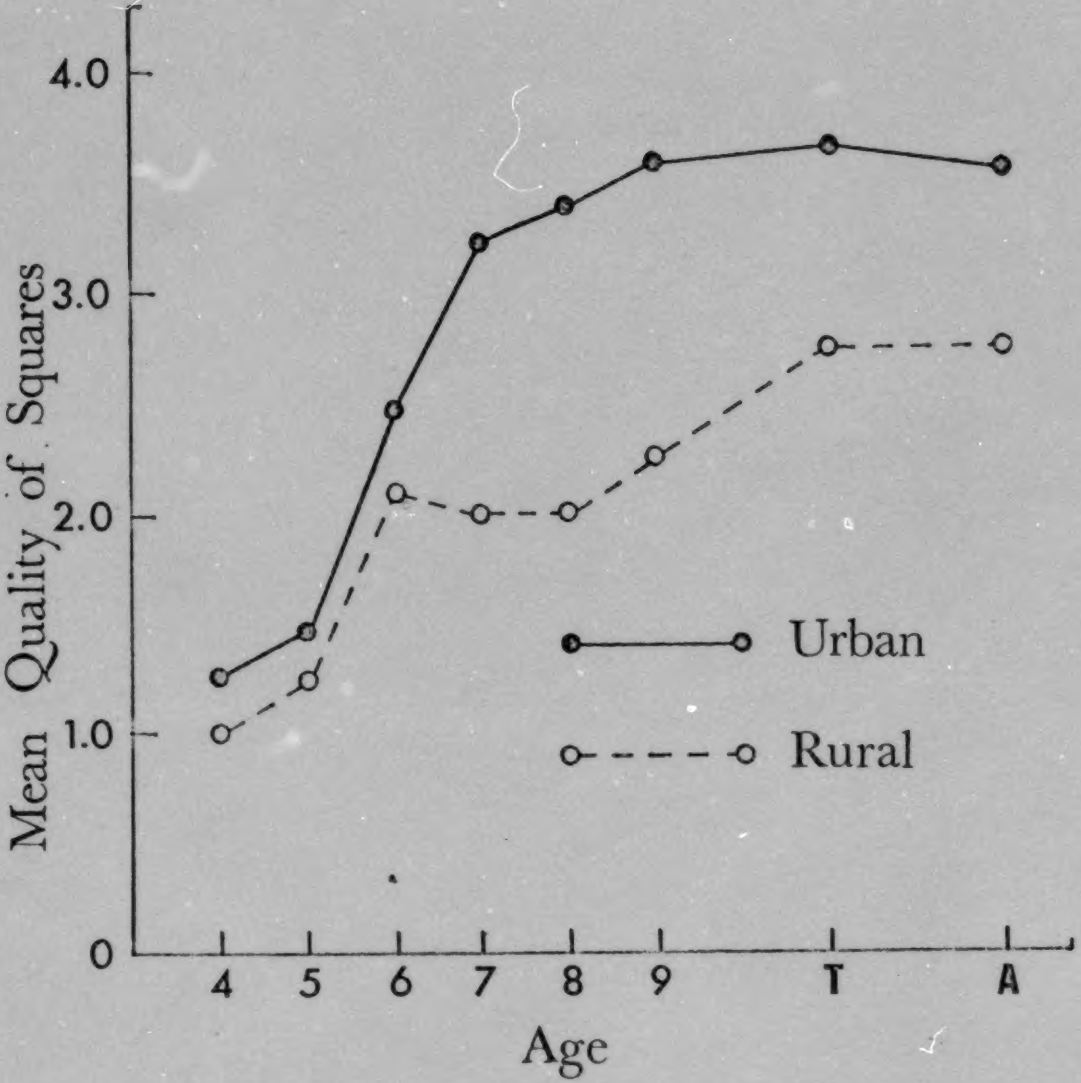


Figure 35 Mean quality rating of squares, by age and sample. N: as in figures 28 and 29.

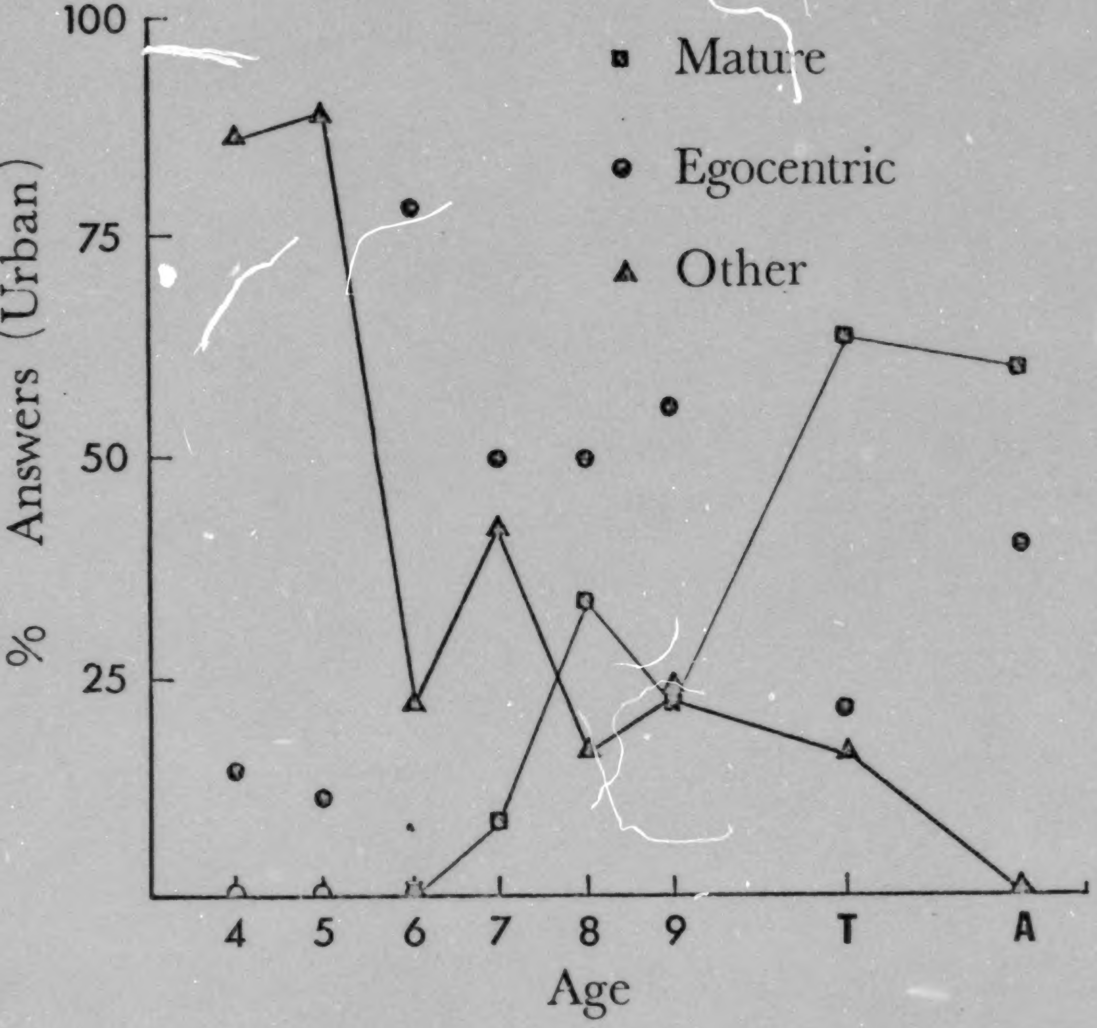


Figure 36 Percentage of urban subjects giving mature, egocentrentric, and other answers to the Brothers task by age. N: 7, 9, 9, 12, 6, 9, 19, 5.

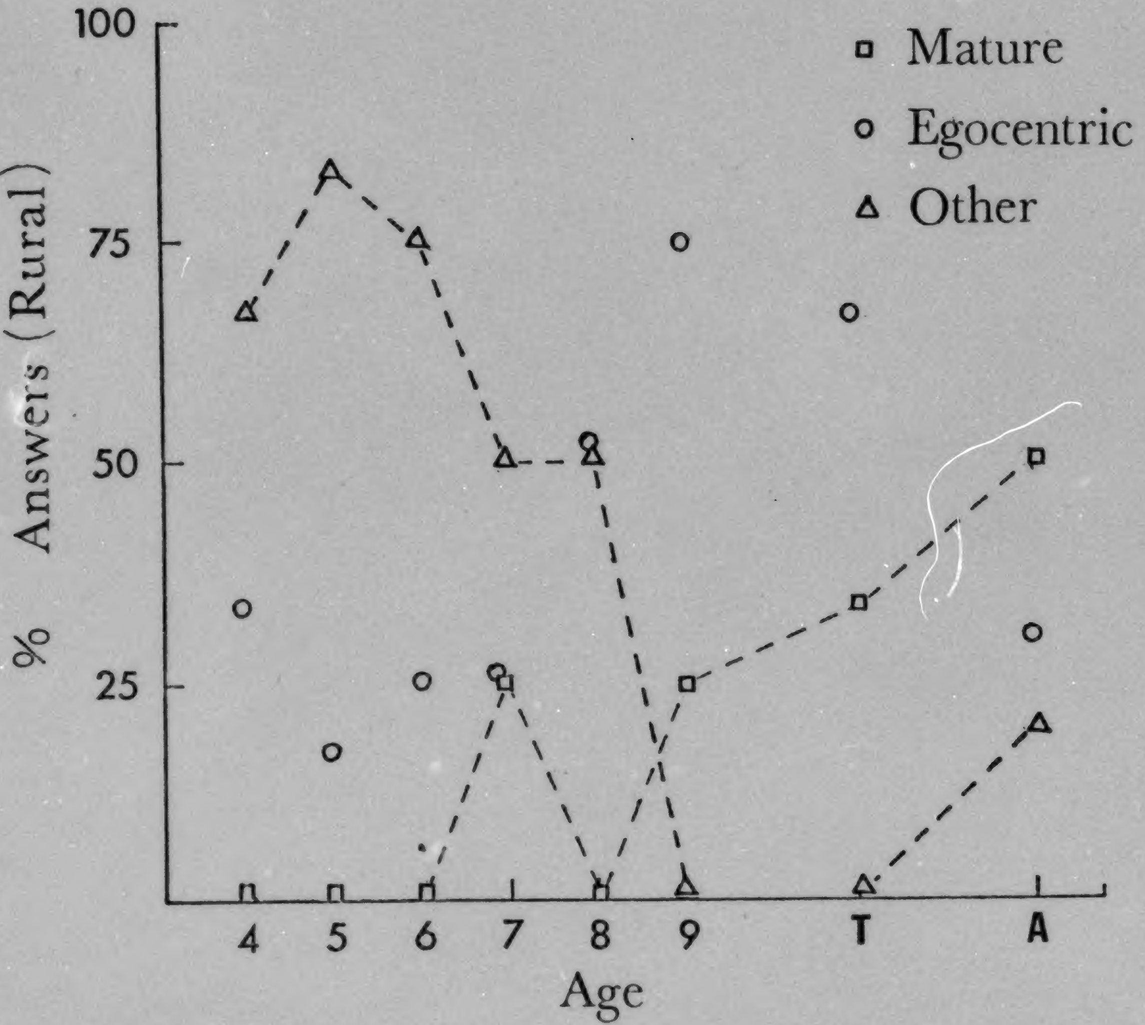


Figure 37 Percentage of rural subjects giving mature, egocentric, and other answers to the Brothers task, by age. N: 3, 6, 4, 4, 4, 4, 6, 10.

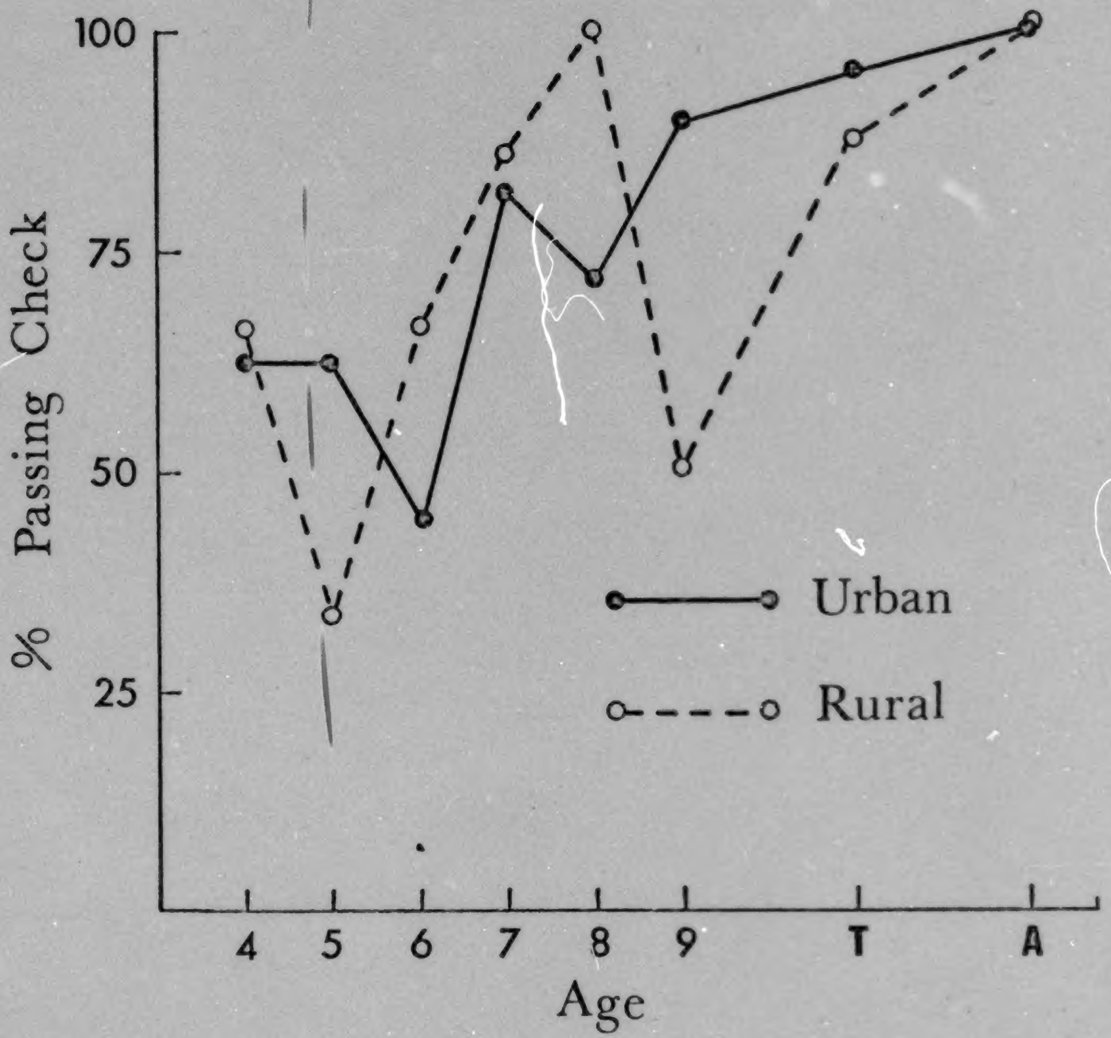


Figure 38 Percentageof subjects passing trapezoidal check item, by age and saple. N urban: 8, 8, 9, 11, 7, 10, 21, 7; rural: 3, 6, 6, 7, 4, 4, 8, 10.

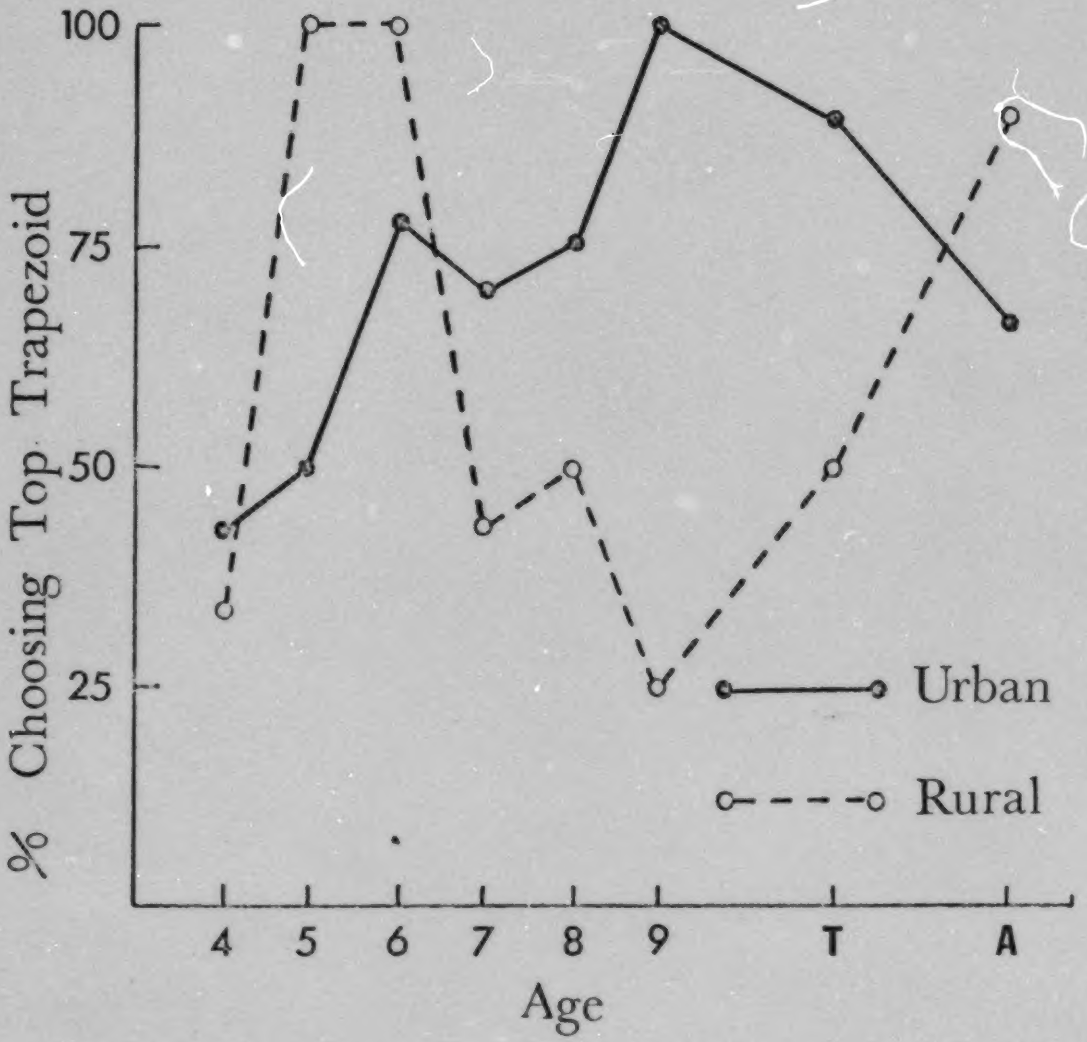


Figure 39 Percentage of subjects choosing the top trapezoid on trial 1, by age and sample. N urban and rural: as in figure 38.

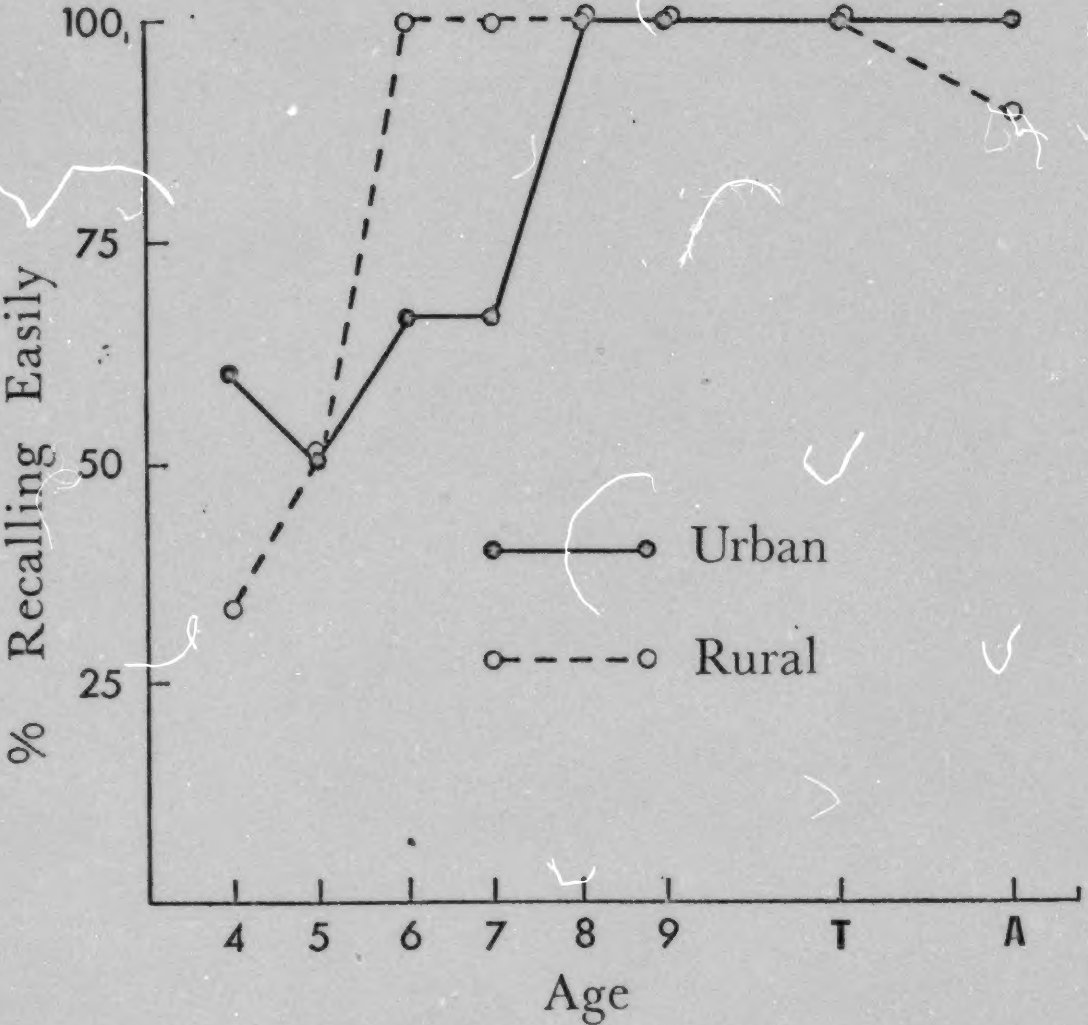


Figure 40 Percentage of subjects proceeding without difficulty through the recall task, by age and sample. N urban: 5, 8, 9, 9, 5, 7, 12, 7; rural: 3, 6, 4, 4, 4, 4, 7, 10.

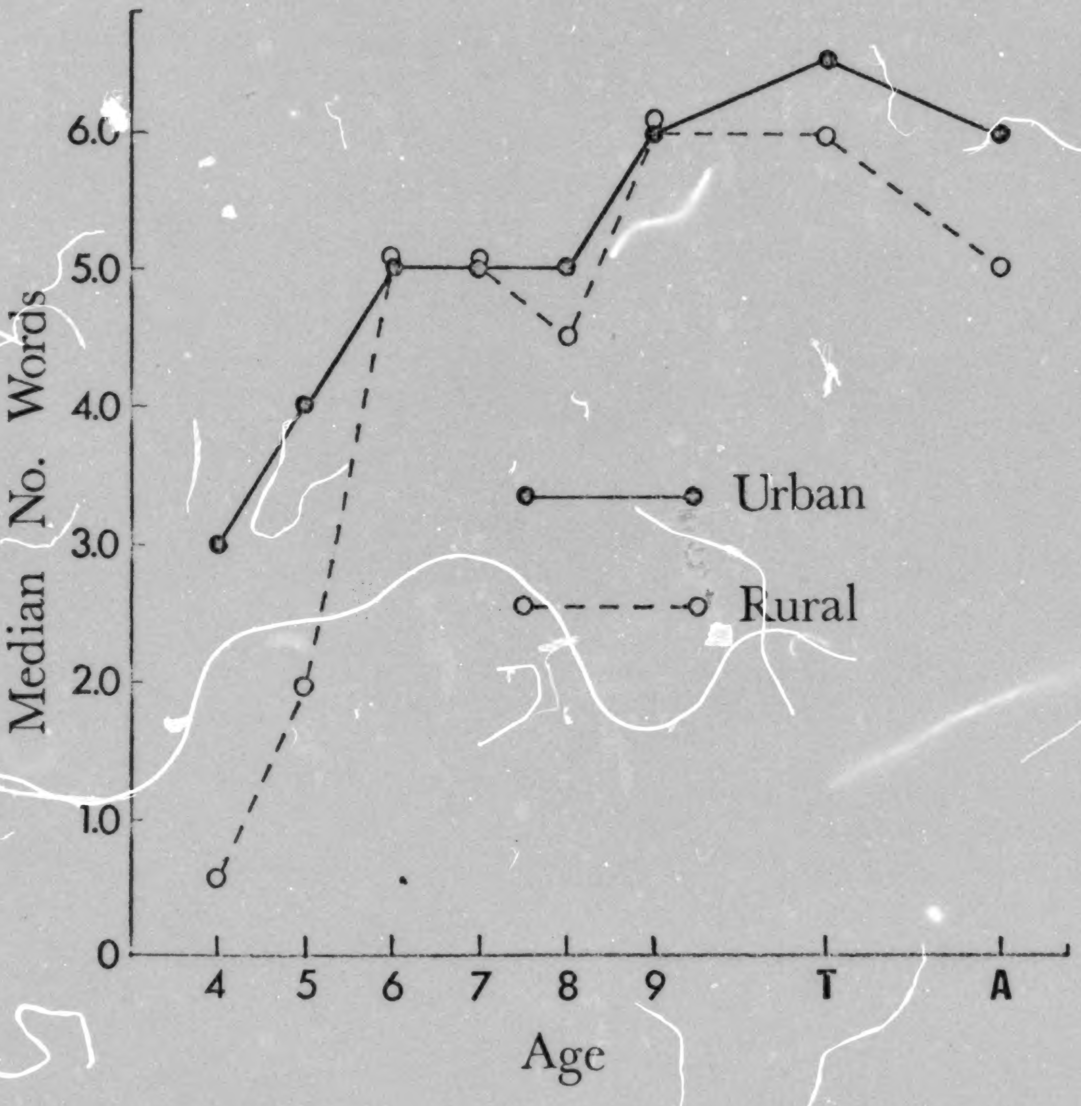


Figure 41 Median number of words recalled on trial 1, by age and sample

N urban and rural: as in figure 40.

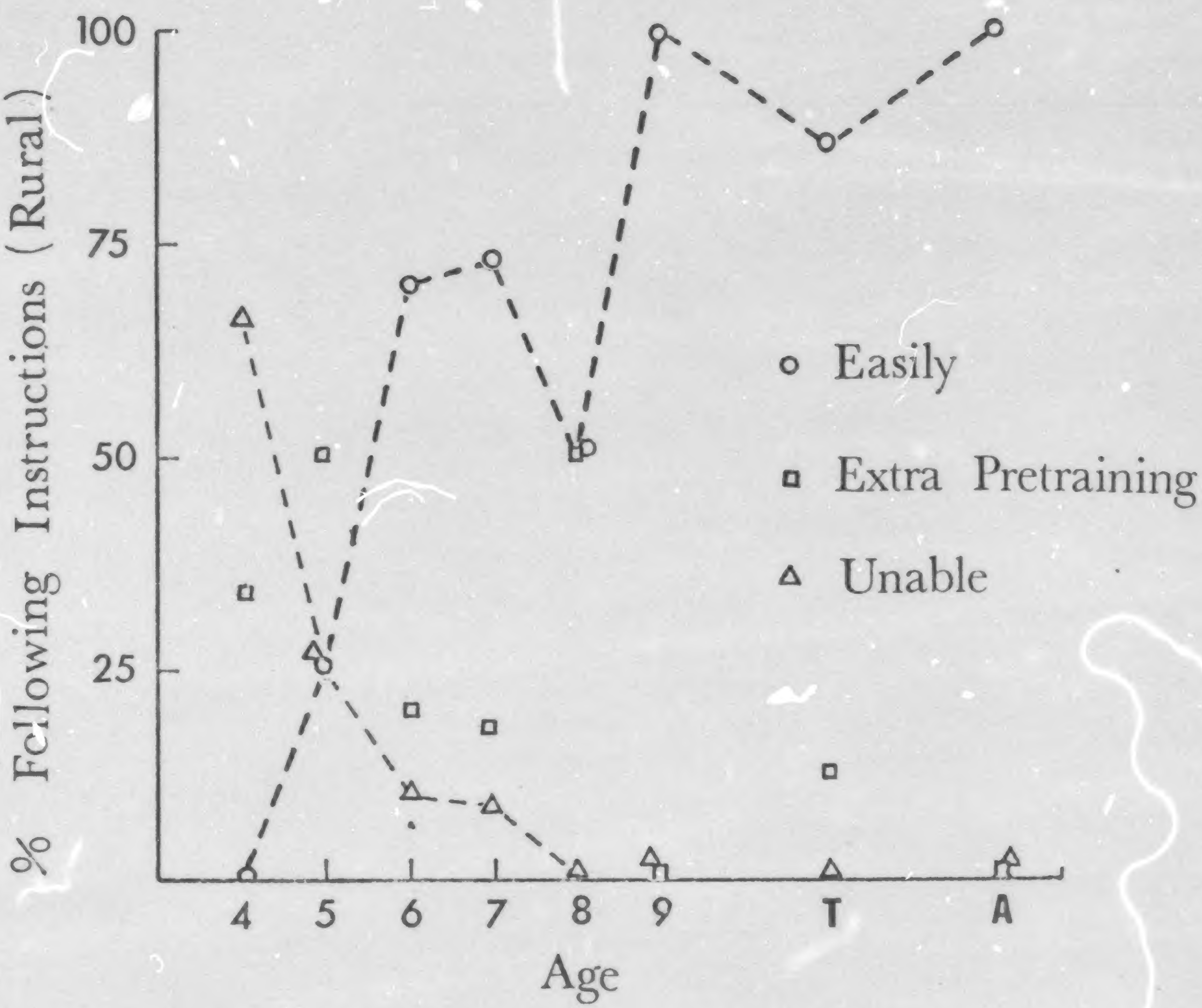


Figure 43 Percentage of rural subjects following the Face-Hands instructions easily, needing extra pretraining, and unable to continue, by age. N: 6, 12, 10, 11, 8, 8, 15, 20.

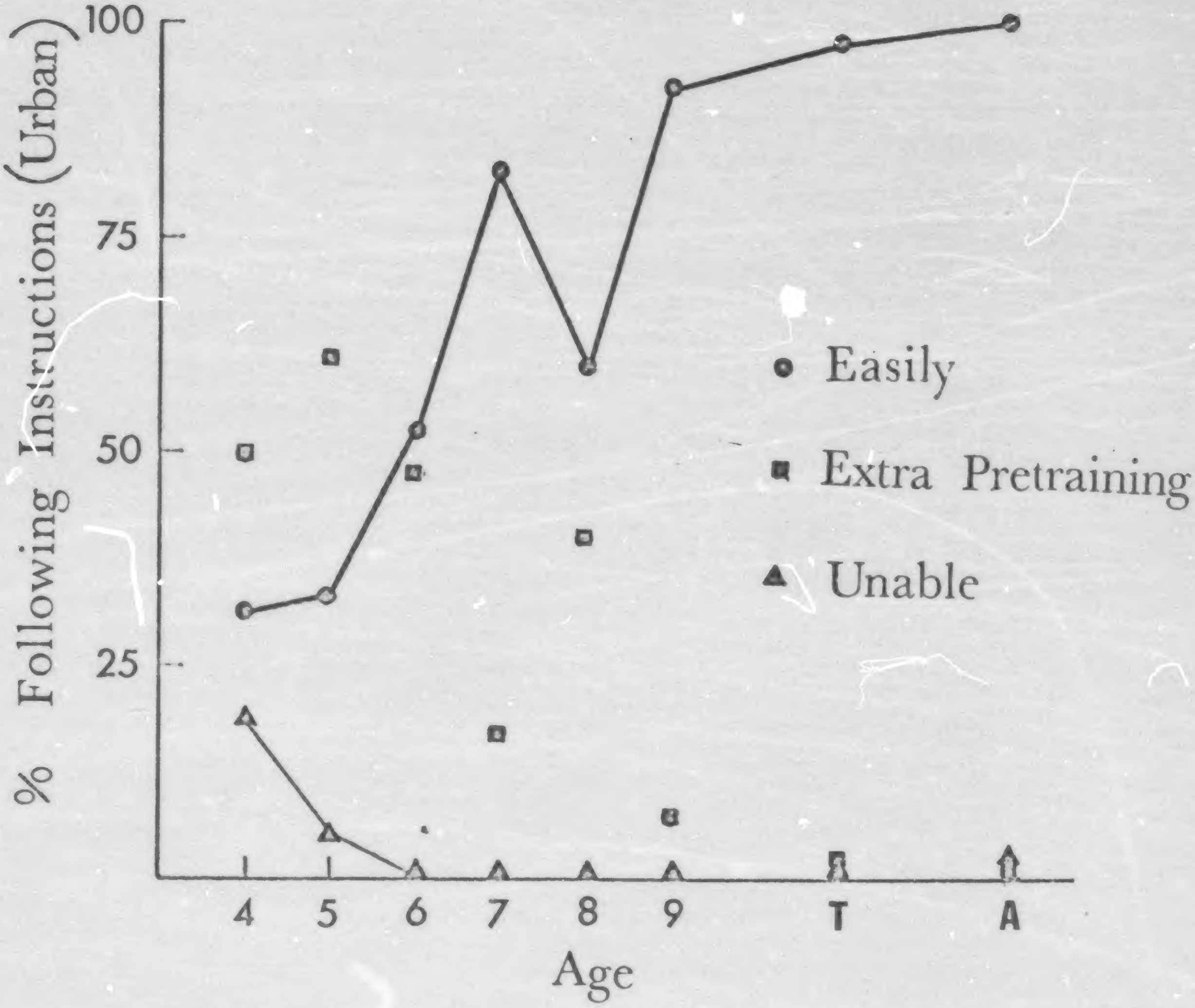


Figure 42 Percentage of urban subjects following the Face-Hands instructions easily, needing extra pretraining, and unable to continue, by age. N: 16, 18, 19, 23, 15, 27, 42, 16.

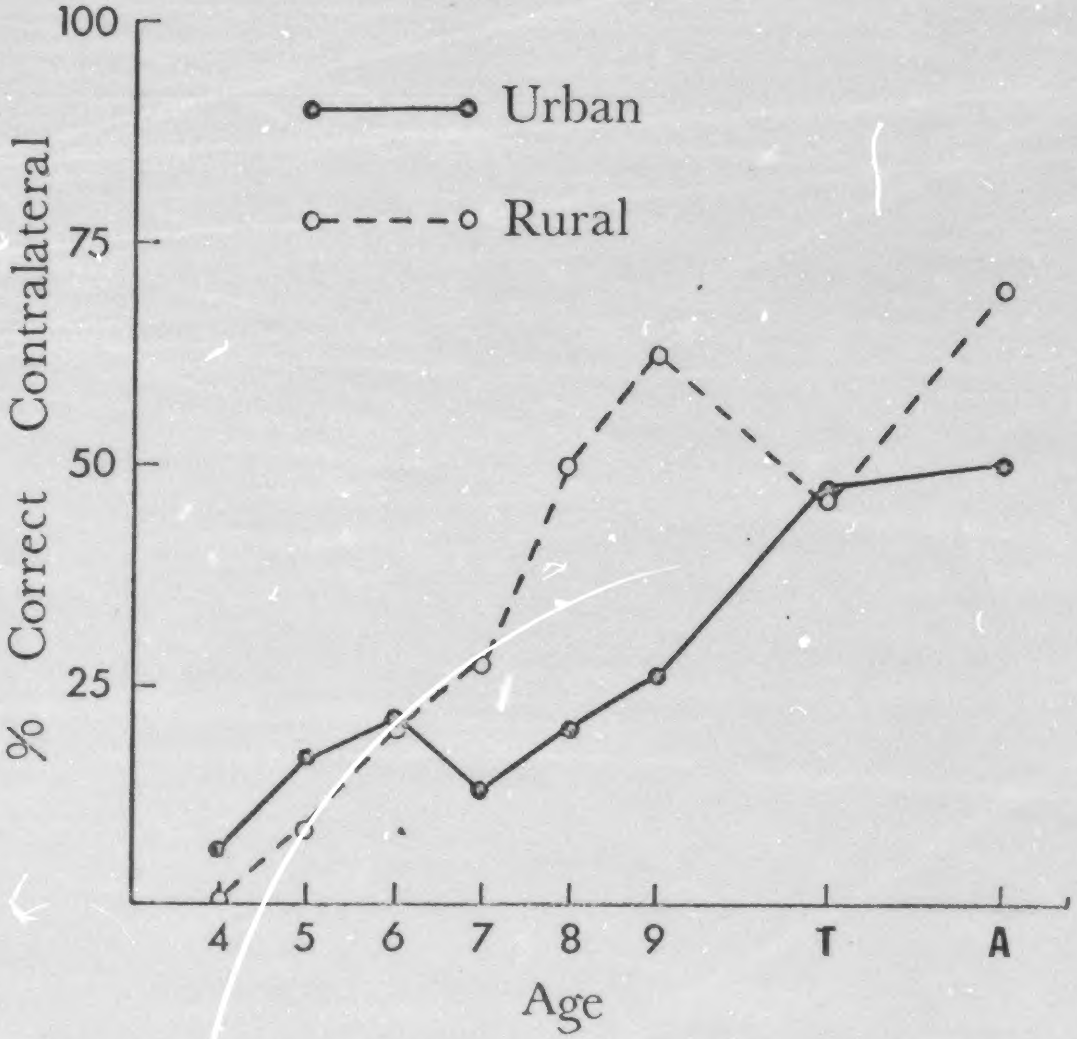


Figure 44. Percentage of subjects responding correctly to both contralateral items, by age and sample. N urban: 16, 18, 19, 23, 15, 27, 42, 16; rural: 6, 12, 10, 11, 8, 8, 15, 20.

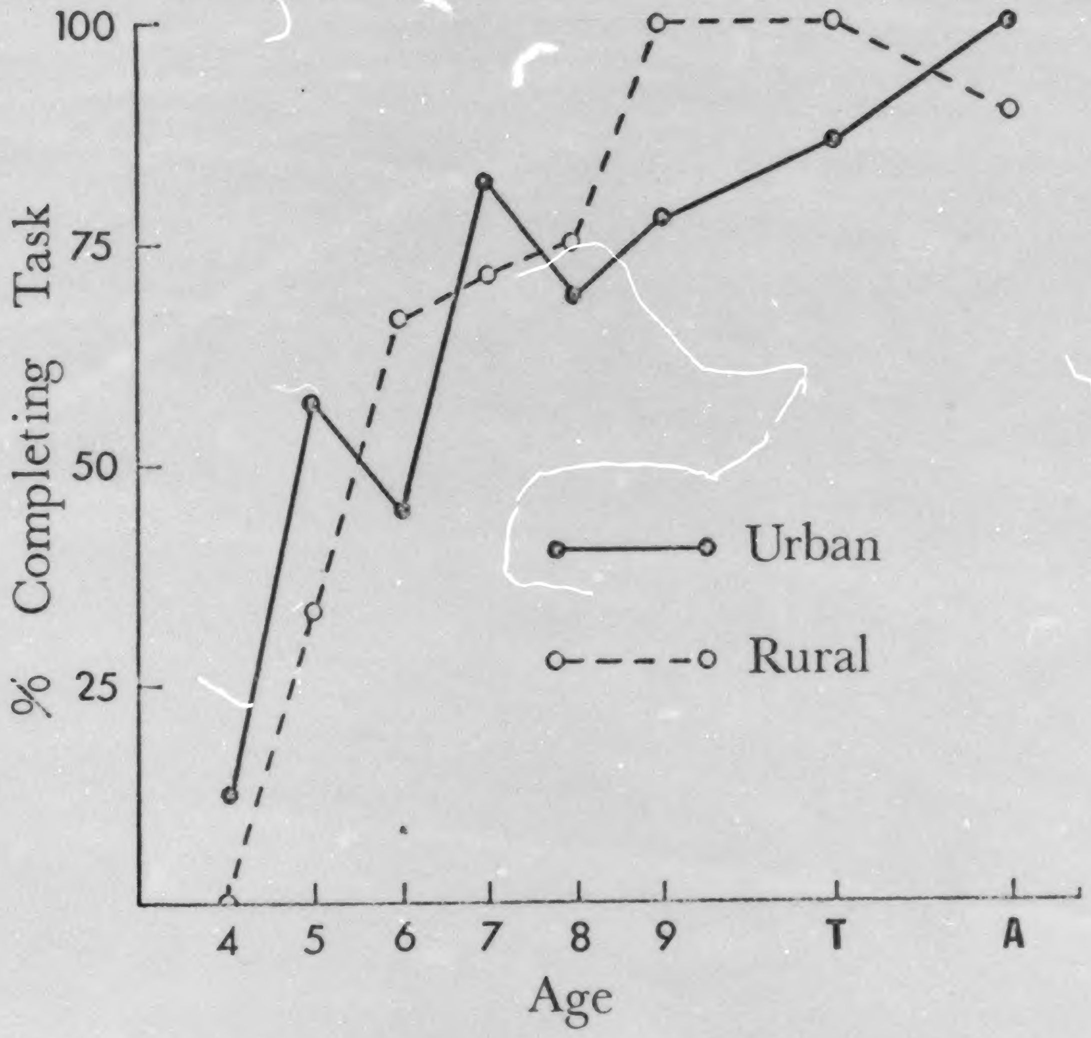


Figure 45 Percentage of subjects completing the signal detection task, by age and sample. *N* urban: 8, 7, 9, 11, 7, 9, 15, 7; rural: 3, 6, 6, 7, 4, 4, 8, 10.

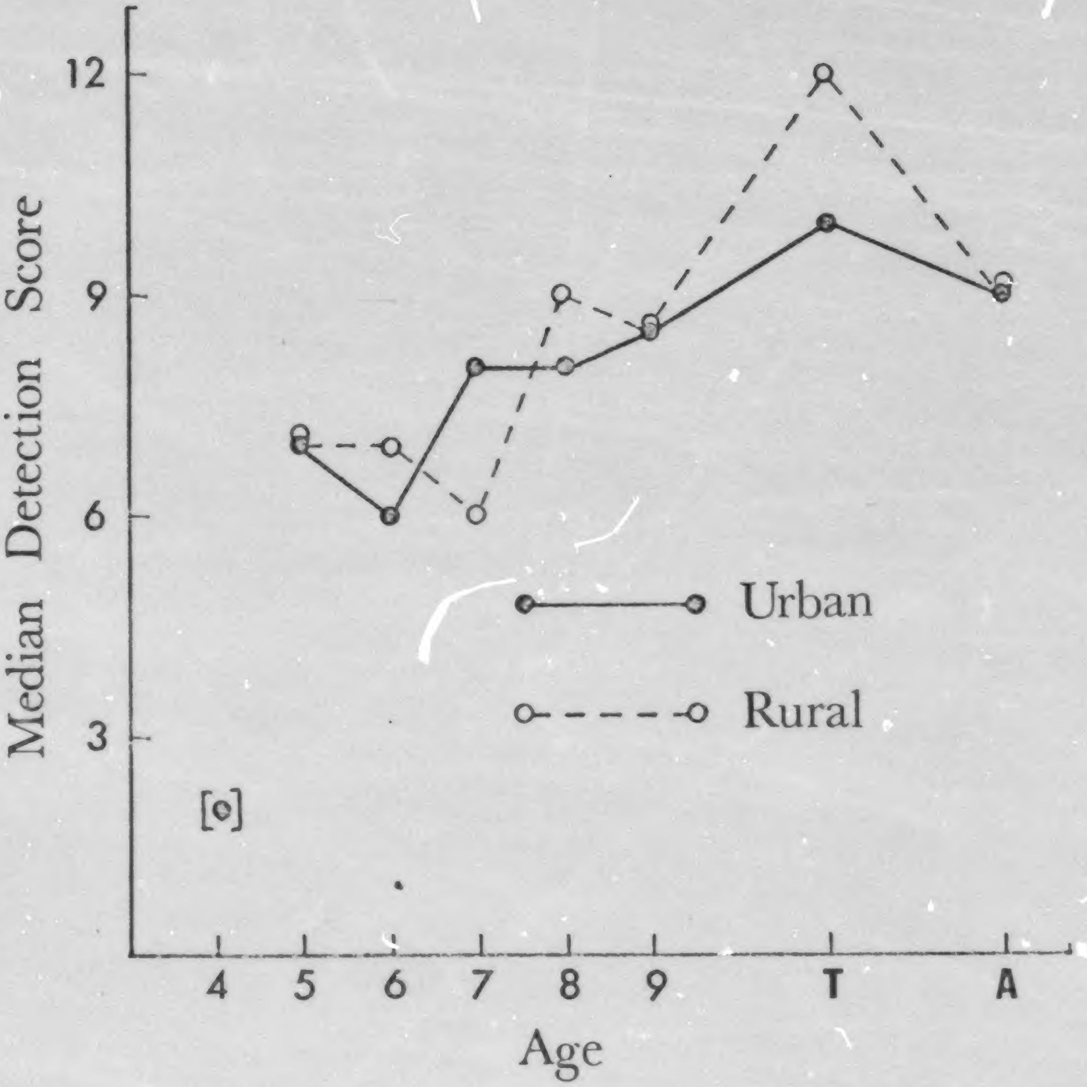


Figure 46 Median number of signal detection items correct, by age and sample. N urban: 1, 5, 6, 11, 5, 8, 15, 7; rural:0, 3, 4, 5, 3, 4, 8, 10.

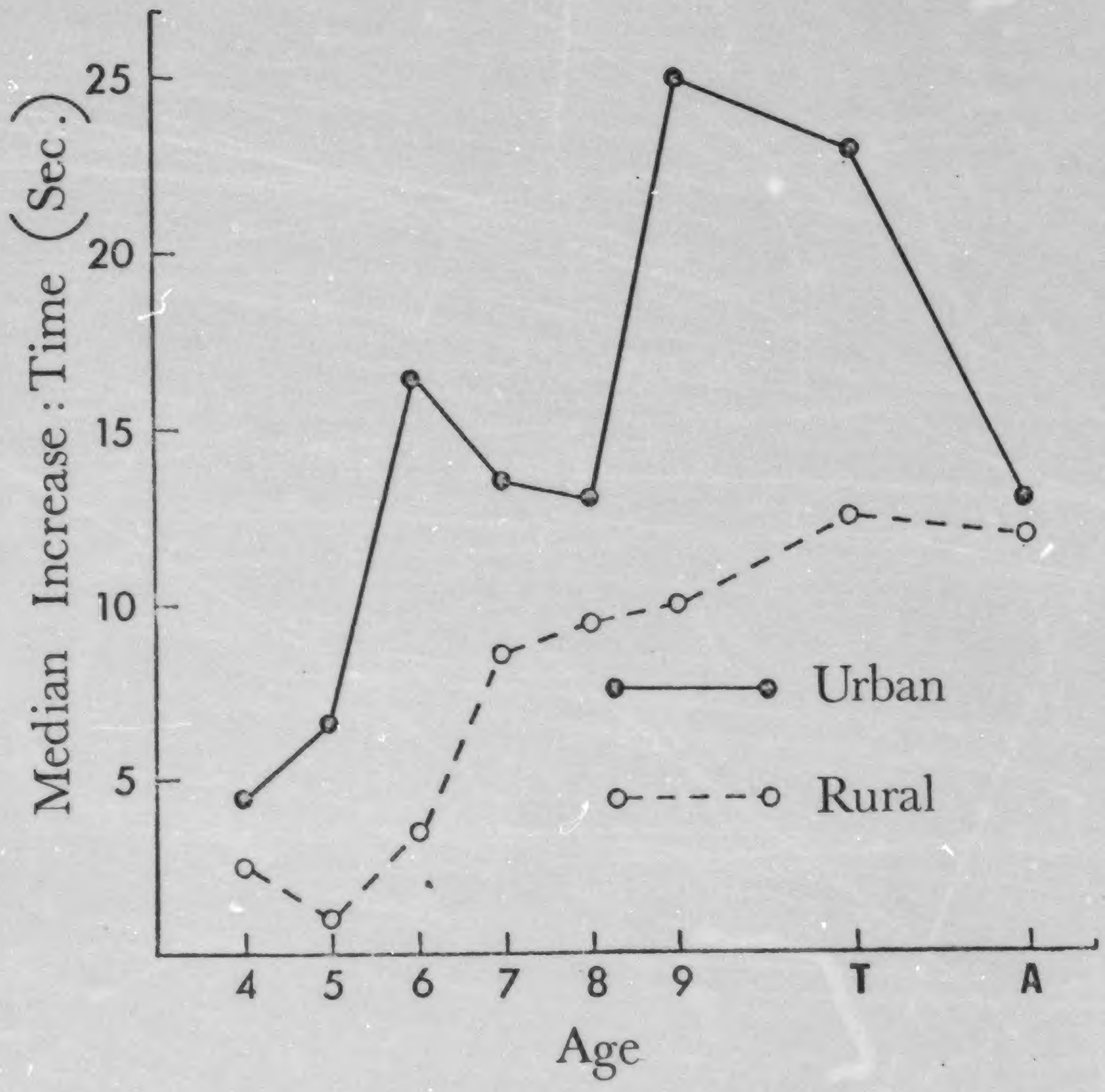


Figure 47 Median increase in time for speaking under DAF in seconds, by age and sample. *N* urban: 7, 7, 8, 11, 6, 9, 18, 7; rural: 3, 5, 6,7, 4, 4, 8, 10.

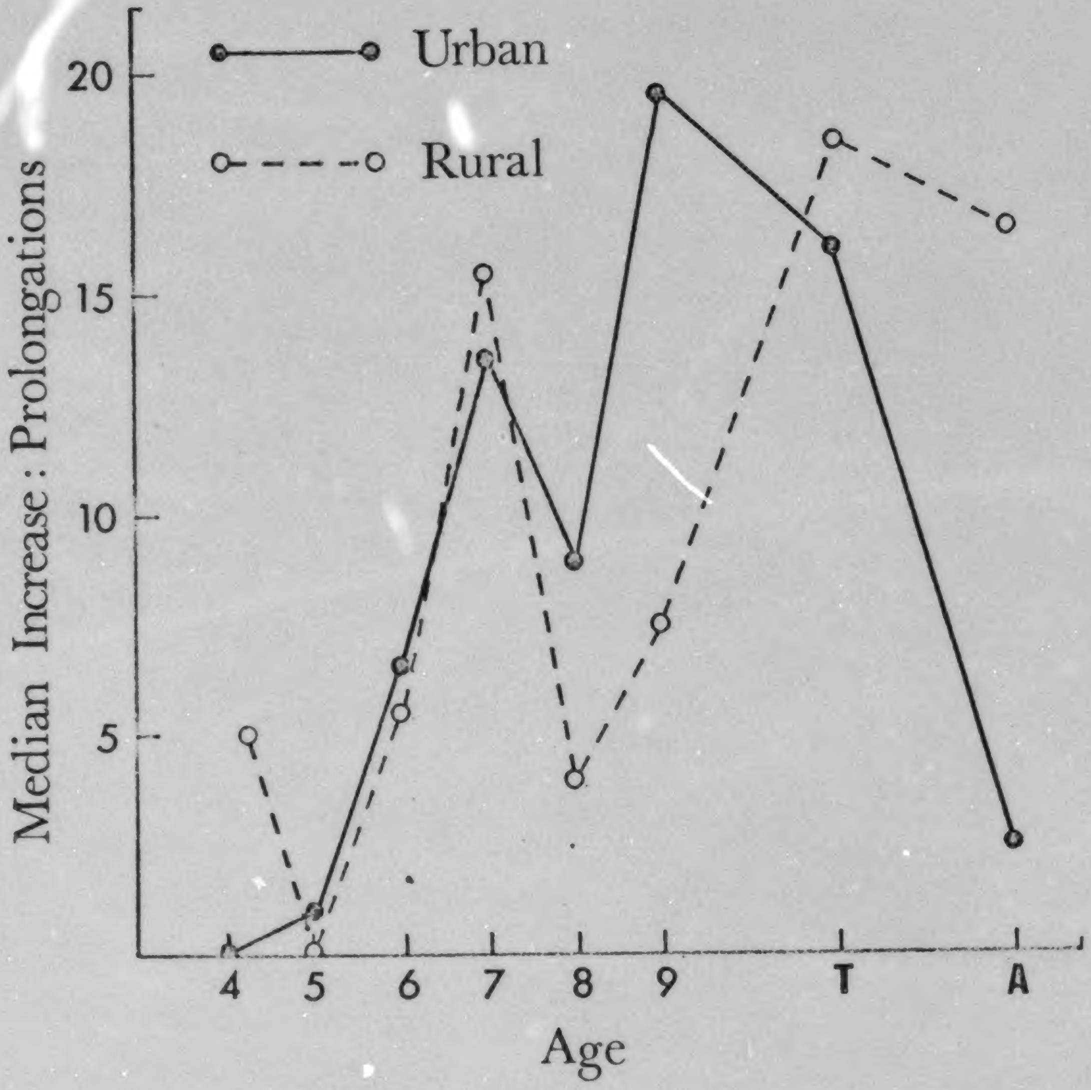


Figure 48 Median increase in number of prolongations while speaking~~xx~~ under DAF, by ~~xhx~~ age and sample. *N* urban and rural: as in figure 47.

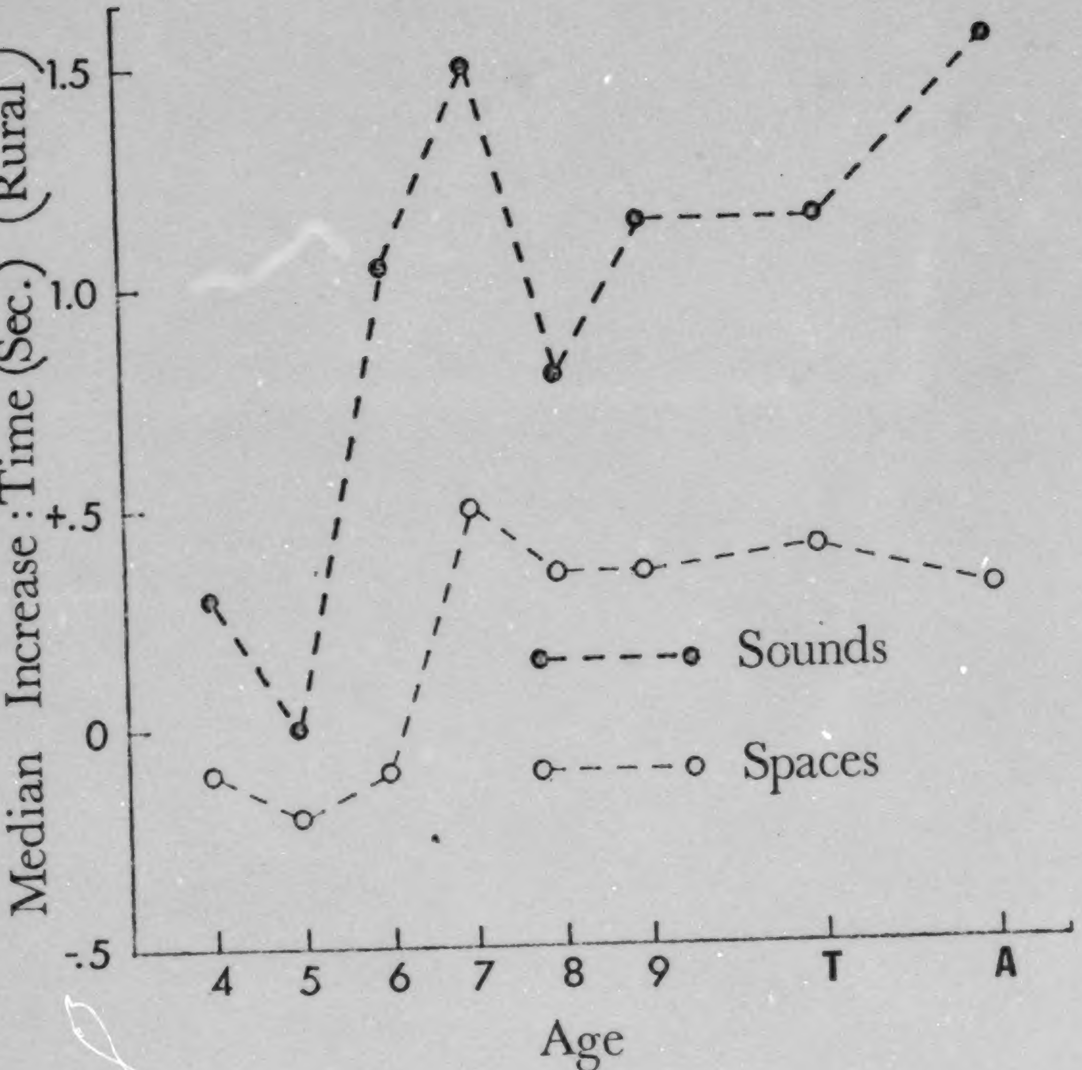


Figure 49 Median increase in time during sounds and between sounds, under DAF, rural subjects by age. N: as in Figure 47.

THE CORRELATION BETWEEN SOME MEASURES OF NEUROLOGICAL AND COGNITIVE DEVELOPMENT IN THE YOUNG CHILD

QUALIFYING PAPER

SUBMITTED BY

CHARLES EDWARD GUNNOE

OCTOBER, 1970

THE CORRELATION BETWEEN SOME MEASURES OF NEUROLOGICAL AND COGNITIVE DEVELOPMENT IN THE YOUNG CHILD

Developmental psychologists have had an enduring interest in the activity of the nervous system. Freud (1895) started his Project for a Scientific Psychology in hopes of describing the neurological mechanisms responsible for thought and action. Werner's (1948) organismic approach has as one of its aims the discovery of how different aspects of an individual's psychophysiological functioning interrelate. Piaget (1952) considers the maturation of the nervous system as one important aspect of the development of intelligence. While the force of argument tips the scales in support of the importance of establishing relationships between neurological and cognitive development, the weight of evidence barely budges them.

In some cases the evidence exists but waits for someone to integrate it. White (1965) has catalogued and described numerous changes which occur in the child during the 5-7 age range. These changes occur along diverse developmental lines. White argues than an understanding of how these changes interrelate may require a neuropsychological explanation. The amount and rate of change taking place in the child and the proposed need for a neuropsychological approach makes this age range optimal for a study of neurological and cognitive relationships.

This qualifying paper describes a series of studies with six year old boys undertaken to explore these relationships. The selection of neurological and cognitive measures will be discussed, followed by a report of each of the studies.

A brief search through the pediatric neurology literature reveals a paucity of data concerning the normal development and maturation of the nervous system. There are at least two reasons for this: the first is one of priorities. Pediatric neurology is a medical speciality and as such places emphasis on diagnosing and treating abnormal conditions. The second is a state of the art problem. Pediatrics is a relatively young area of medical specialization. It has yet to develop a sophisticated methodology for the study of central nervous functions. The electroencephalograph provides a direct means of monitoring nervous system activity but little is known about how to interpret this electrical activity from a normal developmental standpoint. Techniques exist for the determination of the structure of the nervous system (e.g. dissection, histology) but these methods require destructive experimentation not applicable to intact human beings.

The resulting situation is one that finds the pediatric neurologist making many inferences about the intactness of segments of the nervous system from behavioral data. In certain cases this method is straight forward. For instance, a determination of the portion of the visual field in which a patient cannot perceive a stimulus allows fairly precise localization of impairment. However, the degree of neurological maturity of a sensory system or a particular portion of the brain cannot be unequivocally assesed by this method. Until more is known about the relationship between structure and function in the central nervous system one must rely on behavioral data and age norms in assessing neurological development. One cannot yet determine on the basis of behavioral data, what part of, or the degree to which, the nervous system has developed but only how this data compares with that of other subjects.

There exists therefore the necessity of using indirect behavioral measures to assess neurological variables. For the studies to be reported such tests were selected that required no complicated apparatus, and could be administered in a relatively short period of time. Other criteria for selection were the existence of data on inter-rater reliability and a developmental progression in performance level. Several tests of associated movement met these criteria.

Associated or synkinetic movements are movements accompanying a motor or intended motor function but not necessarily needed for its performance. They are usually contralateral and symmetrical to that limb which is voluntarily active. For example, the closing of the left hand while trying to make a fist with the right. These movements are of value in clinical diagnosis (especially in cases of minimal cerebral dysfunction) and in assessing neurological maturity (Connolly & Stratton, 1968).

Fog and Fog (1963) have used these movements to study cerebral inhibition. They argue that the development of this inhibition is necessary for the acquisition of detailed, discriminative motor activity. The results of their study show a steady decrease in the incidence of associated movements with age. They attribute this to the fact that excitatory mechanisms develop earlier than inhibitory ones. They used two tests: one bilateral (associating movement from feet to hands) and one crossed (associating movements from one hand to the other). With a sample of 265 normal and 184 mentally retarded children they found that these movements became inhibited in the course of childhood. This effect was greater in the normal than in the retarded group. Within the retarded group those suspected of having organic brain damage were most different from the normal group.

Zazzo (1960) and his collaborators have studied several of these associated movements and devised a test based on finger lifting. Using Zazzo's finger lifting test and the Fogs' clip pinching test, Abercrombie et al (1964) investigated the responses of 23 normal children (mean age 9 years, 1 month) and 50 physically handicapped children, including 26 with cerebral palsy. Generally the cerebral palsied children were found to be outside the normal range. However, the small discontinuous sample of normal children made it difficult to establish a valid normal range.

Connolly & Stratton (1968) developed another test of associated movement based on finger spreading. They administered this test, a modified version of Zazzo's finger lifting test, the fogs' clip pinching test, and the feet to hands test to 658 normal children. The children ranged in age from 4 years 9 months to 15 years 8 months. The incidence of associated movements decreased with age. They also found the tests differed with respect to the age range of maximal sensitivity (sensitivity was defined as the age range within which more than 20% but less than 80% of the children in a particular age group showed no associated movements): clip pinching 5-13 years, feet to hands, 8-13 years, finger spreading, 10 years to beyond the age range tested, finger lifting from 5 years onwards. The correlations between the tests were all positive and largely significant.

To assess the reliability of the examiner's judgment regarding the presence or absence of associated movements thirty raters were trained as scorers. They were shown movies of 5 children being tested and scored.

Their ratings were compared to the examiner's. The raters and the examiner agreed an average of 86.8% of the time.

The studies being reported in this paper used the same tests as did Connolly & Stratton. A detailed description of the tests and scoring criteria will be discussed later.

Another test of associated movement was adapted from the Ozeretsky test of motor performance (Sloan, 1955). This test requires the subject to touch each finger of one hand to the thumb of the same hand in order starting with the index finger and again starting with the little finger.

One more test was used to assess the neurological variable in this series of studies. A shortened version of the Bender Visual-Motor Gestalt Test (1938) was included. The Bender requires the subject to copy sample designs. Failure to copy a design correctly may be due to a deficit in either visual processing or motor performance. The Bender test has been used as a test of visual-motor performance to diagnose brain injury and emotional disturbances, and as a predictor of school achievement. Koppitz (1964) has integrated research using the Bender with children ages 5-7 and has developed an objective scoring system for the test.

In order to reduce testing time a shortened form of the test was used. Super (1970) provided the rationale for using three designs in place of the original 10. The three figures used are examples of designs employing dots, closed figures and lines. Bender (1938) argued these were essential components of the test. In addition these three designs provide the best coverage of the five scoring categories proposed by Koppitz (1964). The test will be described in more detail later.

As with neurological development there exists no direct way of assessing cognitive development. Here too one must rely on some behavioral index of performance and infer what is going on inside the child's head. The most complete and systematic developmental theory of cognitive structures is that proposed by Piaget (e.g. 1952, 1958, 1964).

Piaget views cognitive development as a process of biological adaptation. This process represents a developmental change in the way a subject perceives and transforms experience. His experiments with children have persuaded him to view this development within a stage theory model. Accordingly, a child at a particular stage of reasoning approaches problems and arrives at their solutions in a consistent manner that can be described by a set of rules. Each stage has its own coherent set of rules. Tanner (1953) has argued that Piaget's descriptions of these stages resemble descriptions of developmental progressions in biochemical and physiological systems.

Piaget describes the 5-7 year old child's cognitive behavior as relying progressively less on such specific attributes of a stimulus object as form and shape and more on such abstract concepts as quantity, weight and volume. The child becomes able, for instance, to conserve the concept of quantity even when a stimulus object changes its shape.

Another type of cognitive task developed by Piaget requires the child to use the concepts "some" and "all" appropriately when responding to questions about geometrical figures. He has found that the child also masters this task during the 5-7 period.

Piaget proposes that the mechanism which accounts for a child's ability to solve such problems is "decentering," e.g. when faced with a transformation in two dimensions the child takes into consideration not only the most salient perceptual dimension of change but also the other dimension . He makes a similar argument for the "some" and "all" task. In this case the child who does not answer the questions correctly is "centering" on one of the stimulus elements to the relative exclusion of the others.

In the present study two conservation tasks and the "some" and "all" task were used to assess the cognitive variable. A detailed description of the tasks and thier scoring follows.

Study I: Weston, Massachusetts

Problem:

This study was conducted to determine the correlation between the previously mentioned measures of cognitive and neurological development.

Method:

Subjects: Thirty Caucasian boys in the first grade of a public elementary school were selected as subjects on the basis of age. All the boys who were between 6.0 and 7.0 years of age were eligible. The experimenter exhausted 4 of the classes with eligible boys and took 4 subjects from the remaining class. The mean age of the sample was 6.54 years with a standard deviation of 0.27 years and a range of 6.1 to 7.0 years. Parents' occupation was used as an estimate of SES level. Twenty two of the thirty subjects could be classified according to Duncan's (1961) occupational scale. This scale runs from 0 (lowest level) to 100 (highest level) based only on parents' occupation. The mean SES for the 22 was 79.59 with a standard deviation of 14.7 and a range of 37-96.

An IQ estimate was obtained for each child on the basis of an individually administered Peabody Picture Vocabulary Test. The mean IQ for the sample of 30 was 119.17 with a standard deviation of 15,98 and a range of 96-152.

Procedure

E was introduced to each S by the teacher. Outside the classroom E told S that he "was interested in how boys his age learned to do some things with their hands and how they played some special games." S was then asked if he would like to come play some ganes with E. All S's wanted to participate.

S was seated in a chair near a desk in a quiet room. After a brief conversation (how many children are in your family? what is the part of school you like best? etc.) the experimental session began. The o rder of presentation of tasks was invariant. On each task S was allowed as much time as he wished.

The following tests were administered. Total testing time ranged from 25-40 minutes.

Neurological Tests

1. Bender Gestalt (Bender, 1938) cards A, 2 and 5. S was given a sheet of plain 8½ x 11 inch paper and a pencil. E said, "I want you to copy this picture. Make yours look as much like this as you can. Take as much time as you wish." This procedure was repeated for each card. S's reproduction was scored according to Koppitz's (1964) system. S's preferred hand was noted.

2. Clip Pinching (Connolly and Stratton 1968). S was told to put his hands on the table and make a fist as E was doing and then spread his thumbs so they pointed toward each other. E then placed a 2 spring (bulldog) paper clip in between the thumb and fist of S's preferred hand and asked S to see how far he could open the clip. This was repeated for the nonpreferred hand. S was given a score of 1 (associated movement) if the thumb of the contralateral hand touched the fist.

3. Finger Spreading (Connlly and Stratton 1968). E demonstrated to S the spreading of the third (middle) from the fourth (ring) finger of each hand in turn. S was asked, "Hold both hands out with your fingers together and then try to spread these fingers as I do while keeping the rest together." If S succeeded in spreading the finger indicated without fingers on the contralateral hand spreading a score of 0 (pass) was given.

A score of 1 (fail) was given for each of the following conditions: inability to spread only the assigned fingers, associated movements of contralateral hand. Each child could get a score from 0-2 for each hand.

4. Finger Lifting (after Connolly and Stratton 1968 and Zazzo 1960). S was told "Place both hands flat on the table and try to lift just the fingers I point to without lifting the others." Following a demonstration the test was carried out on the third finger of the preferred hand, third finger of the other hand, fourth finger of preferred hand and fourth finger of the other hand in that order. The child was given one point for each of the following conditions on each trial: a) inability to lift the appropriate fingers without lifting any other fingers on the same hand; b) lifting any fingers on the other hand while trying to lift the appropriate finger. A score of 0 was given for each successful trial.

5. Finger Apposition (after Sloan, 1955). S was told to place his elbows on the table with his hands open and arms pointing up. E then demonstrated touching the fingers of his right hand to his thumb in order starting with the index finger. This was repeated starting from the little finger and working backwards. S was then told to repeated what he had just seen with the hand E pointed to. E always started with S's preferred hand. One point was given for each of the following conditions: a) inability to touch each finger to thumb in turn; b) flexion of fingers or thumb on other hand during a trial. A score of 0 was given for each successful trial.

6. Feet to hands (Connolly and Stratton, 1968, Fog and Fog, 1963). S was told to stand facing the E and "let your arms hang down by your sides." The E then demonstrated the task by inverting his feet and walking on the outside edges of them (distance of six feet). S was then instructed to do what he had just seen. A score of 1 was given if there was supination or pronation in the hands. A score of 0 was given for successful performance.

The following chart summarizes the range of scores possible on each neurological test. A higher score indicates a poorer performance:

Test	Range
Bender-Gestalt	0-9
Clip Pinching	0-4
Finger Spreading	0-4
Finger Lifting	0-8
Finger apposition	0-4
Feet to hands	0-1

Total range 0-30

Cognitive Tests

1. Deformation of clay (after Piaget 1950). S was given two balls of clay (play-doh) with approximately the same amount of clay in each (diameter 1.5"). He was told to make them so "that one ball has just as much clay in it as the other one." He was further told "when you finish each ball should have just as much clay as the other one." After the S was satisfied that each ball had the same amount of clay E performed three deformations on the clay balls. S was told to watch what E did. After deforming one of the balls E ashed "Do they still have the same amount of clay or does one have more than the other?" After S answered he was asked why he thought so and then asked to make the deformed clay into a ball again. He was further instructed to make it so that each ball had the same amount of clay just as before. The following deformations were performed:

1) Sausage - E rolled ball into sausage shape approximately one inch long.

2) Pancake - E pressed ball into a flat disk approximately the size of his palm (diameter, 4").

3) Balls- E made one of the balls into 10 small balls and placed them in a line.

For each deformation a score of 1 (nonconservation) or 0 (conservation) was given. On the basis of these three scores S was assigned to one of the following three categories for deformation of clay task:

Nonconserver - Total score of 3

Transitional - Total score of 1-2

Conserver - Total score of 0

2. Cups and Circles (after Piaget, 1950) - egg and eggcup experiment - E placed ten small paper cups 1" apart in a row in front of S. He then gave S a cup full of cardboard circles (each about the size of a dime) and asked him to put a circle in front of each cup so that "there will be just as many circles as cups." After S completed this task he was asked if there were the same number of circles as there were cups. After agreeing that there were, S was presented with the following transformation: E moved the cups 2" apart and asked S whether there were still the same number of cups as cricles or whether there were more of one or the other. E then asked why he thought so.

S was then asked to put the cups back like they were before. After he agreed that there were the same number again he was presented with another transformation: E moved the circles 2" apart and asked the same questions as in the previous transformation.

For each transformation S was given a score of 0 if he said there were still the same number of objects and 1 if he said that there were more of one type than the other. S's total score was the sum of the two transformation scores and on the basis of this score each S was assigned to one of three categories:

Nonconserver - Total score of 2

Transitional - Total score of 1

Conserver - Total score of 0

3. Concepts of "some" and "all" (classification) (after Piaget 1964). E placed a row of circles (1" in diameter) and squares (1" on a side) in front of S in the following order from his left" purple circle, purple square, purple circle, purple circle, purple square, red square, purple

circle, red square, purple circle. Then E placed a pile of red squares, a pile of purple circles, a pile of red circles and a pile of purple squares on the table. E asked S: "If you had to make a row of things just like the one in front of you and you could use as many of these piles as you needed which ones would you use? Point to the ones you would use."

E removed the piles and said "Now I am going to ask you some questions, you can answer all of them by looking at the row of things in front of you."

The following questions were asked:

1) Are all the purple things circles?

2) Are all the square things red?

3) Are all the circles purple?

4) Are all the red things squares?

If S made no mistakes he was a conserver, if he made 5 mistakes he was a nonconserver. If he made 1-4 mistakes he was transitional. His final score was based on which of three categories he fell into:

Nonconserver - Total score of 2

Transitional - Total score of 1

Conserver - Total score of 0

The following chart summarizes the range of scores possible on each cognitive test. A higher score indicates a poorer performance:

Test	Range
Play Doh deformations	0-2
Cups and circles	0-2
"Some" and "all"	0-2

Total range: 0-6

Results:

	mean	s	range
Neurological tests	9.80	2.83	5-16
Cognitive tests	2.70	1.76	0-5

The Pearson Project moment correlation between the neurological and cognitive test scores was +0.60 ($t=3.84$, $p < 0.005$). (See Appendix, Figure 1).

Correlations were computed between neurological and cognitive tests partialling out both age and IQ:

$r_{\text{neurological, cognitive x age}}$ + 0.56 ($t=3.57$, $p < 0.005$)

$r_{\text{neurological, cognitive x IQ}} = 0.57$ ($t=3.68$, $p < 0.005$)

Conclusions:

The data shows a significant positive correlation between the measures of neurological development and the measures of cognitive development. This correlation cannot be accounted for by either age or IQ.

Study II: Cambridge, Massachusetts

Problem:

Is there a correlation between the neurological and cognitive measures with subjects of lower SES and IQ than the Weston sample?

Method:

Subjects: Thirty Caucasian boys in the first grade of a public elementary school were selected as subjects on the basis of age. All but one of the boys was between 6.9 and 7.1 years of age. The other boy was 7 years 4 months and was the youngest subject available to complete the sample. The entire population of eligible subjects in three schools was selected. For the study the mean age of the sample was 6.59 years with a standard deviation of 0.29 and a range of 6.17 to 7.33 years. The mean age of this sample is not significantly different from that of the Weston sample ($z=0.73$, ns $p < 0.05$).

Again parents' occupation was used to estimate SES level. Seventeen of the 30 subjects could be classified. The mean SES was 28.35 with a standard deviation of 13,68 and a range of 12-53. This mean is significantly lower than that of the Weston sample ($t=21.26$, $p < 0.005$).

An IQ estimate was obtained by individually administering the Peabody Picture Vocabulary Test. The mean IQ for the sample was 98.23 with a standard deviation of 13.03 and a range of 62-125. This mean was significantly lower than that of the Weston sample ($z=5.57$, $p < 0.01$).

Procedure and Method:

The procedures and methods used with the Weston sample were replicated with the Cambridge sample.

Results:

	mean	S	range
Neurological tests	11.13	3.81	4-19
Cognitive tests	3.87	1.33	1-5

The mean of the neurological tests does not differ significantly from that of the Weston sample ($z=1.53$, ns, $p < 0.05$). The mean of the cognitive tests is significantly higher than that of the Weston sample ($z=2.93$, $p < 0.05$).

The Pearson Product moment correlation between the neurological test scores and the cognitive test scores is = 0.72 ($t=5.62$, $p < 0.005$) (See Appendix, Figure 2). This correlation is not significantly different from that of the Weston sample ($z=0.82$, ns, $p < 0.05$).

Correlations were computed between the neurological and cognitive tests partialling out both age and IQ:

$r_{\text{neurological, cognitive x age}} = 0.74$ ($t=5.85$, $p < 0.005$)

$r_{\text{neurological, cognitive x IQ}} = 0.69$ ($t=5.07$, $p \; 0.005$)

Conclusions:

With a sample of boys lower in IQ and SES but of the same age as the Weston sample a positive correlation between neurological scores and cognitive scores was again found. This correlation does not differ statistically from that of the Weston sample. Again it cannot be accounted for by either age or IQ. The mean cognitive score of the Cambridge sample is higher than that of the Weston sample. The difference between the mean neurological scores approaches but does not reach significance with Cambridge having the higher mean score (for 0.05 level need t of 1.64, t value is 1.53).

Study III - Cambridge, Massachusetts

Problem:

How reliable are the neurological measures?

Method:

Subjects: 28 of the 30 original Cambridge subjects made up the sample

(1 child broke an ankle, the other was sick).

Procedure:

Each child was given the neurological tests a second time. The mean number of days between 1st and 2 nd testing was 21.07 with a standard deviation of 8.34 and a range of 9-35 days. This time the tests were administered in a way such that each performance had 2 trials. (For computational purposes trial 1 was used as a subject's score.) Except for this modification the procedure was the same as before.

Results:

Two estimates of reliability were computed: between trials and test re-test. The following Pearson Project moment correlations were obtained:

$r_{\text{between trials}} = +0.93$ ($t=13.67$ $p < 0.005$)

$r_{\text{test retest}} = +0.75$ ($t=5.80$, $p < 0.005$)

(see Appendix, Figure 3 for test retest reliability).

The second set of neurological scores had a mean of 11.04, a standard deviation of 3.26 and a range of 4-18. This mean is the same as that for the first set of scores.

The Pearson Product moment between the second set of scores and both age and IQ were computed:

$r_{\text{neurological II} \times \text{IQ}} = -0.23$ ($t=.21$ ns $p < 0.05$)

This correlation is not significantly different from that found in Study I ($z=0.73$ ns $p < 0.05$)

$r_{\text{neurological II} \times \text{Age}} = -0.18$ ($t=0.94$ ns $p < 0.05$)

This correlation is not significantly different from that found in Study I ($z=0.57$, ns $p<0.05$)

Conclusions:

The inter trial reliability of the neurological measures is high. The test retest reliability of these measures is moderately high. It is possible that enough time had elapsed between tests for some of the subjects to have undergone developmental changes in these variables. In this situation the correlation might be artificially lowered and therefore not an accurate measure of the stability of the tests. If, however, the 0.75 correlation is an adequate index of the reliability of the tests then the correlation between the cognitive and the neurological tests is approaching the limits of its reliability.

No significant change was found in the relationship between age or IQ and neurological score from 1st to 2nd testing.

Study IV - Weston, Massachusetts

Problem:

Would the original correlation hold over time for the Weston sample?

Procedure:

Subjects: 28 of the original 30 children were retested (1 moved, 1 was sick).

Method:

In order to minimize experimenter bias each child was tested in two sessions, no less than 1 and no more than 7 days apart. The neurological tests were given during the session first and the cognitive measures during the second. To compute the mean length of time between first testing (Study 1) and these sessions, the second testing date was determined in the following way. Since the neurological tests were always given first this testing date plus the mean number of days between the second neurological testing and the second cognitive testing was used as the date of second testing. The mean length of time between first and second testing was 121.75 days with a standard deviation of 10.21 and a range of 109-136 days.

The neurological test items were administered in two trials as in Study 3. While the 1st trial was used for purposes of analysis the comparison of the 1st and 2nd allowed for a check on the intertrial reliability reported in Study 3.

With these exceptions the method was the same as in the first Weston study (Study I).

Results:

	mean	s	range
Neurological scores	7.57	2.08	3-12
Cognitive scores	1.50	1.43	0-5

The means of these scores are significantly lower than the means of the first scores ($z=2.93$, p 0.01).

Comparing individual changes between 1st and 2nd neurological scores reveals only three subjects with a poorer performance on the 2nd test. A similar comparison between the two cognitive tests finds only two subjects getting poorer second scores.

The Pearson Product moment correlation between the neurological score and the cognitive scores is +0.47 ($t=2.73$ $p < 0.01$) (See Appendix Figure 4). This is not significantly different from the original correlation ($z=0.60$ ns $p > 0.05$).

The following correlations were computed between neurological and cognitive scores partialling out age and IQ:

$r_{\text{neurological, cognitive x age}}=+0.47$ ($t=2.73$, $p < 0.01$)

$r_{\text{neurological, cognitive x IQ}} = +0.42$ ($t=2.38$, $p < 0.05$)

As with the Study III the intertrial reliability was high, $r=+0.92$ ($t=12.03$ $p < 0.005$).

Conclusions:

Approximately four months after first testing the Weston sample showed significant improvement in both neurological and cognitive performance. On an individual basis only four subjects performed more poorly the second time on either the neurological or cognitive tests. Despite these changes in the absolute values of the scores a positive correlation between the neurological and cognitive measures was found. As before, this could not be accounted for by either age or IQ.

Summary:

Four studies have been reported that investigated the relationship between measures of neurological development and measures of cognitive development. Two groups of thirty six year old first graders were subjects.

A significant positive correlation was found between a subject's performance on neurological tests and on cognitive tests. This correlation was not significantly influenced by the age, IQ or SES of the subject. Subjects who were followed longitudinally (4 months) showed improvement in performance level without change in the correlation between neurological and cognitive measures.

The intertrial reliability of the neurological items was very high. The short term (three weeks) test retest reliability of the neurological test was moderately high.

The studies reported were designed to identify a phenomenon and establish some of its parameters. No studies have yet been done that provide an explanation for the correlation between the particular neurological tests and the particular cognitive tests. However, the metaphors that have been used to account for success on each of the two kinds of tests are not necessarily mixed.

All the neurological tests except the Bender Gestalt measure associated movement. Fog and Fog (1963) argue that the normal developmental disappearance of these movements depends on "cerebral inhibition." While no one knows exactly what this mechanism might be, it still provides a useful metaphorical rationale.

On the cognitive side, Piaget's metaphor for describing the process involved in a child's ability to succeed on conservation tasks is "decentering". It can be argued that one aspect of this "decentering" might involve the ability to inhibit the first response to a persuasive perceptual change in a stimulus object. This inhibition of response might facilitate taking more than one dimension of change into account on a conservation task. The neurological and cognitive metaphors seem compatible.

Moving from a discussion of the particular tests used in this study to a more general description of what happens to the child from 5-7, one again confronts the inhibition metaphor. White (1966,p.8) finds " . . . an association in a number of studies between impulsive, short latency responses and more juvenile behavior characteristics and long latency responses and more mature behavior characteristics." Kagan (1967, p.508) echoes this interpretation: "One of the processes common to many of the psychological changes can be described as an increase in reflection: an increased tendency to pause, to consider the differential validity or appropriateness of a response; the ability to select the correct response rather than admit one that happens to sit on top of the hierarchy when an incentive stimulus appears." The inhibition metaphor appears to have an extension that at least supports its face validity.

Appendices

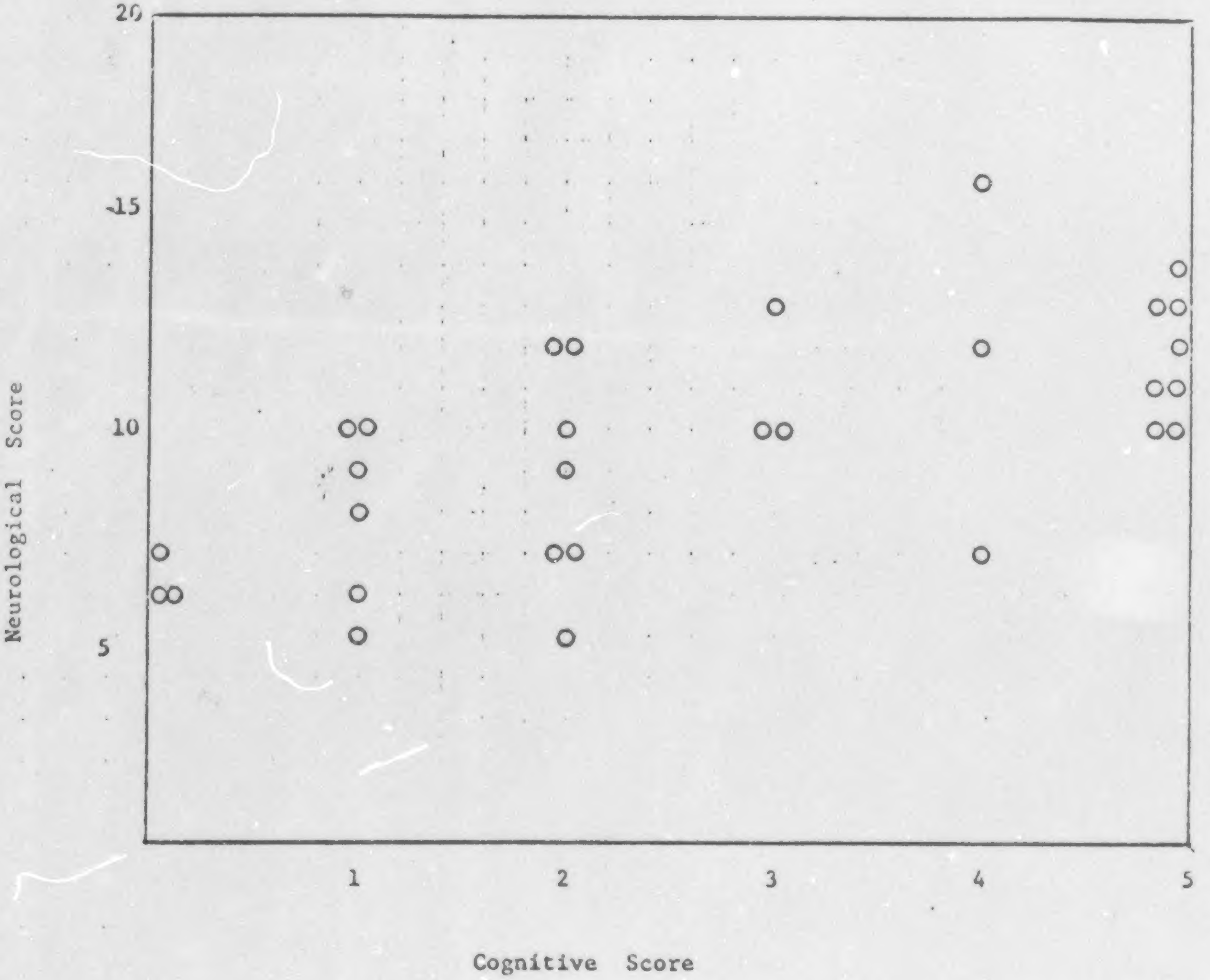


Figure I - Study 1: Neurological Score x Cognitive Score (r= + 0.60)

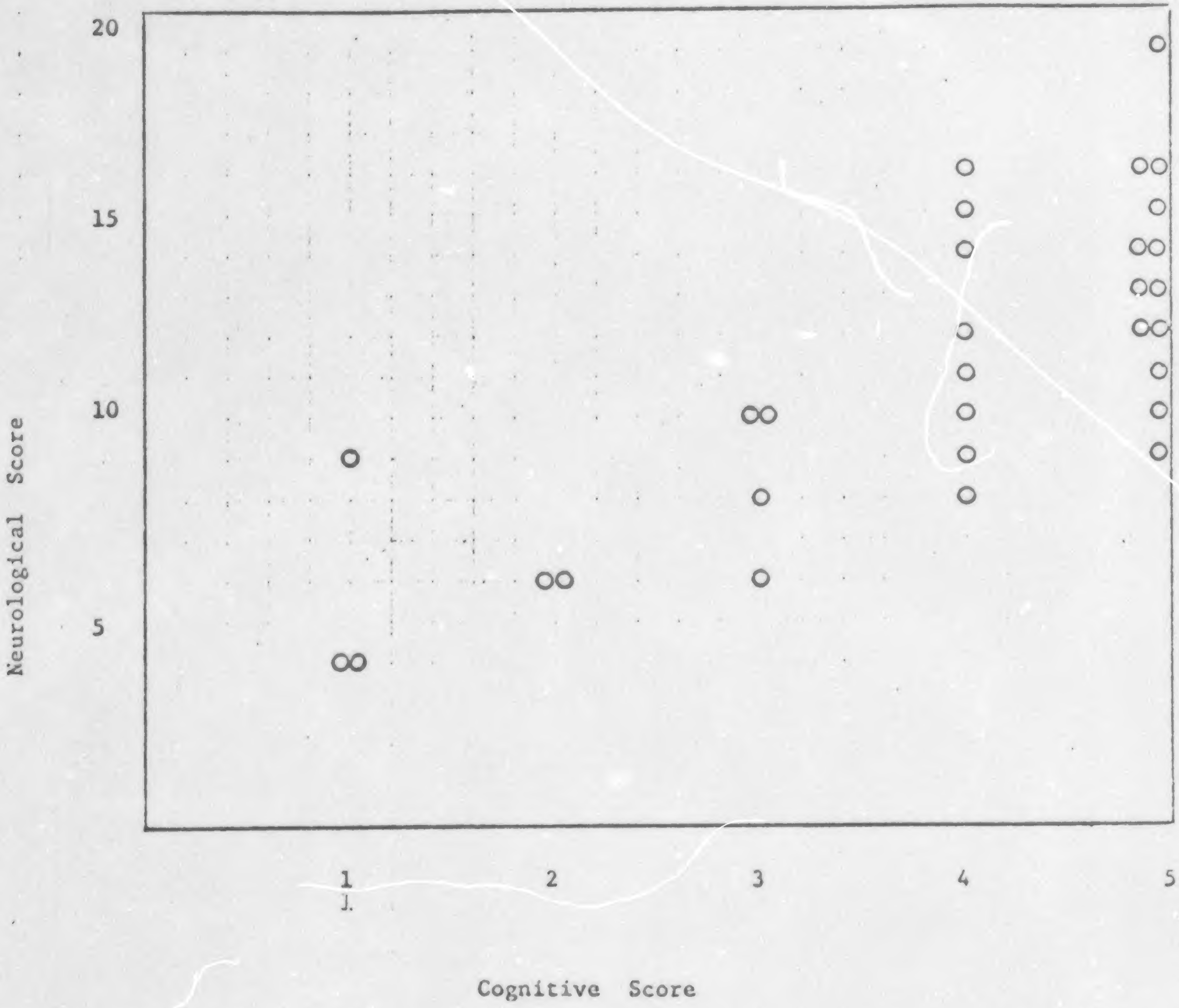


Figure 2 - Study 2: Neurological Score x Cognitive Score (r= + 0.72)

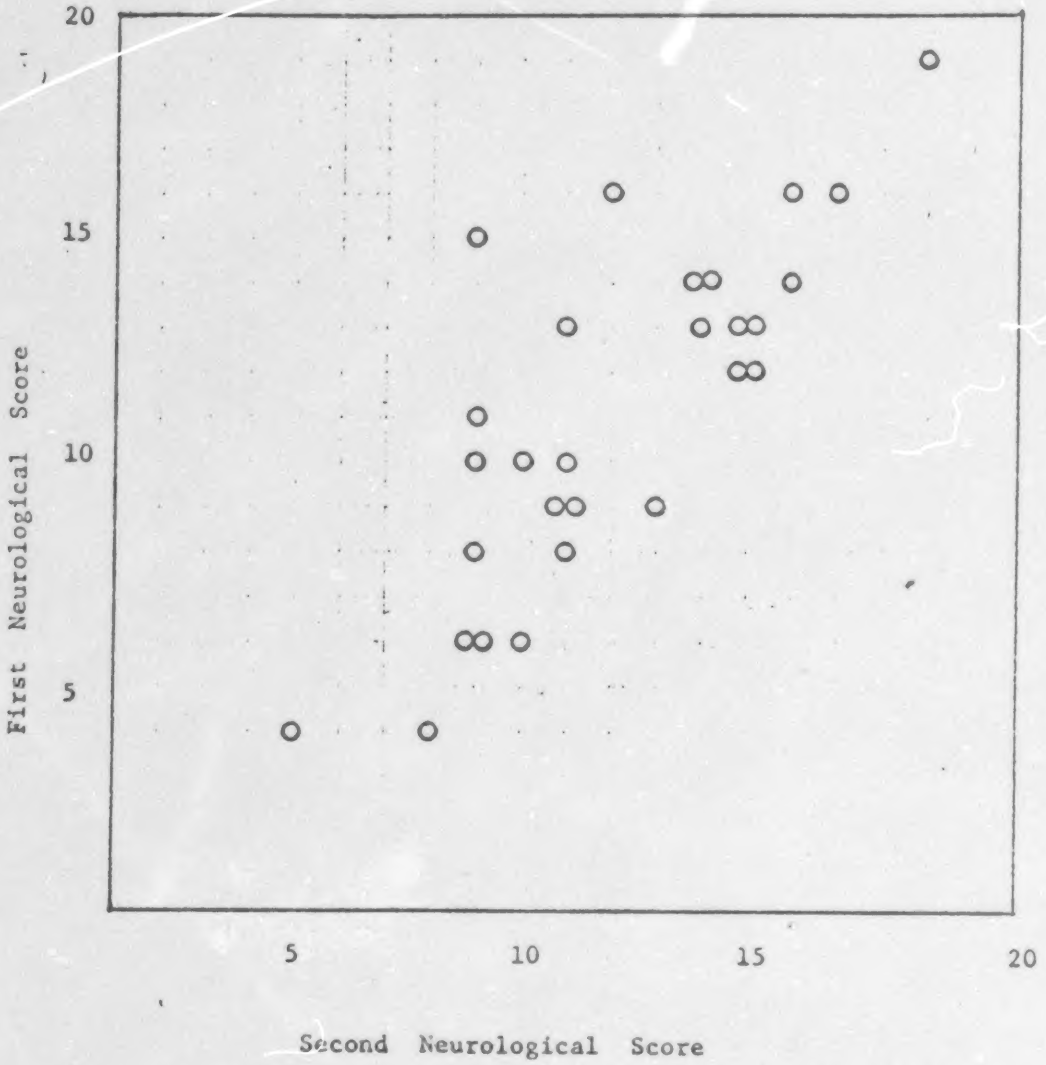


Figure 3 - Study 3: First Neurological Score x Second Neurological Score (r= +0.75)

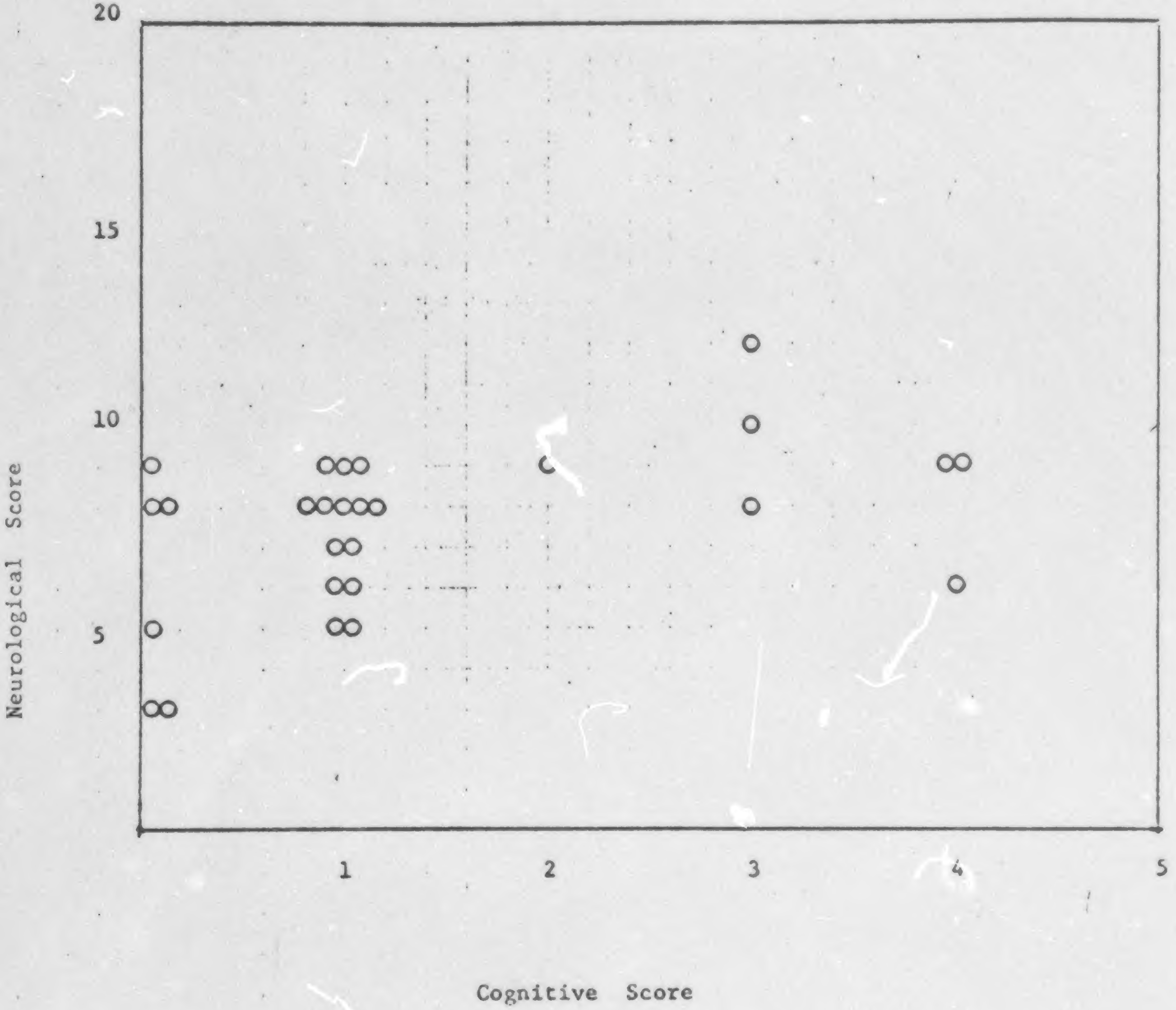


Figure 4 - Study 4: Neurological Score x Cognitive Score (r= +0.47)

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Effects of Visual Noise on Problem-Solving Estimated by an Ascending Method of Limits

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Abstract

Mixed or negative replications of previously reported age shifts in reaction to stimulus variation have been found. The present paper reports a failure to replicate a previously reported (White, 1966) age change in reaction to a varying-position discrimination learning condition. It describes an effort to develop a more efficient format for study of the effects of visual noise on problem-solving. Using an Ascending Method of Limits procedure, graduated amounts of visual noise were added to two discrimination problems, one with constant cues and the other with evolving cues. Thirty fifth-graders coped with our highest noise level when cues were constant, but performance on the evolving discrimination was disrupted by lower noise levels. Poorer-performing Ss were disrupted by middle noise levels; better-performing Ss coped with high noise levels except at times of large changes in the positive cue. In general, it seemed as though the more "cognitive work" the task demanded, the greater was the potentially disruptive effect of the noise.

Effects of Visual Noise on Problem-Solving Estimated by an Ascending Method of Limits[1]

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A number of studies have indicated that at about six years of age children improve in the ability to solve problems involving varying cues (Gollin, 1960, 1961; Walk and Saltz, 1965; White, 1966; Turnure, 1967; Brown, 1969). White (1966) studied two variants of discrimination learning, one in which the positive or negative cue varied, and another in which the cues varied in spatial arrangement from one trial to the next. He found age changes in reaction to both. With regard to the first kind of variant, varying positive or negative cues, Walk and Saltz (1965), and Brown (1969), have also found a comparable age shift. However, they do not confirm the order of difficulty of experimental conditions which White found for older children. With respect to variation of cue position, there are no comparable investigations in the literature but we have recently failed to replicate the original findings of an age shift in sensitivity to this condition.

The study compared Control, Varying-Position, and Late-Varying-Position conditions, the first two conditions identical with those reported earlier, the last a mixed condition in which Ss were exposed to the Control arrangement for their first 20 trials and then, if solution had not come, the Varying-Position arrangement thereafter. With respect to the first two conditions, Control and Varying-Position, the experiment was as exact a replication of the earlier studies as is usually possible for psychological experiments conducted at a different time and place. The apparatus was identical in function and in the face it presented to the S. The E differed. The Ss, drawn from Waltham, Mass., would seem grossly comparable to the original source of Ss. Yet the newer findings, summarized in Table 1, do not confirm the earlier findings. Earlier, it was found that the Varying-Position condition significantly interfered with children's learning at a younger age, after which it became facilitative. Table 1 shows no significant difference in the effects of Varying-Position and Control conditions at any age with, if anything, a trend in the direction opposite to that found earlier.

Insert Table 1 about here.

This pattern of mixed or negative confirmations of originally replicated effects led us to seek a more reliable procedure for the study of the effects of stimulus variation upon learning. The discrimination learning procedure used as a baseline seems inefficient. Each S is confronted with only one level of stimulus variation, and there is something approaching one-item test of its effect. The S solves or does not solve, with problem difficulty quite imperfectly correlated with the trials-to-criterion index.

The present paradigm required the S to make response choices based upon differences in a pair of visual cues. Teh S's ability to do this was tested against not one but a series of noise levels, and this testing was repeated six or seven times in the half hour available for work with the Ss.

Method

An ascending method of limits was used to test the S's ability to cope with graduated increments of visual noise during problem-solving. There were two tasks. The first was a standard two-choice discrimination, and the second was an evolving two-choice discrimination patterned after a previously reported task (White, 1965). The S began each problem with trials on which his choice cues, line drawings, were clearly visible. Then, each time the S responded correctly, an increment of noise was subsequently added to further obscure the choice figures on the next trial. This continued until the S made an error. During the standard two-choice discrimination, almost all Ss were able to sustain correct choices at the highest noise level used, and so Ss were only given one ascending series of noise levels during this problem. During the presentation of the evolving discrimination, when errors at moderate levels of noise were common, the Ss were exposed to repeated ascending tests over the course of 80 trials.

Stimuli. Three sets of stimuli were used: the cues for the simple discrimination, the cues for the evolving discrimination, and the noise figures.

For the simple discrimination, cues consisted of a positive line form vs. a negative line form. There were eight different pairs of such forms used with the Ss to avoid any chance effects of idiosyncratic properties of any particular pair.

The stimuli for the evolving discrimination were constructed from a library of 13 "elements", lines and geometric shapes (See Figure 1).

Insert Figure 1 about here

No element appeared simultaneously in the positive and negative cue, but elements appearing in one cue might later appear in the other cue. Usually a cue consisted of two elements. From trial to trial, change in the stimulus series occurred as these elements were faded in and out. Because of this principle of fading, the amount of change from trial to trial was not constant. There trials for which one element was completely faded out, and the positive stimulus consisted of a single element. To be consistently correct on these trials, a subject had to remember both elements of the positive cue from the previous trial. To choose correctly on other trials, he needed only to remember one of the two elements of the previous positive cue.

The third group of stimuli, those making up the visual noise, were used as overlays for both the constant and everchanging discriminations. Stimuli for the visual noise were constructed from another library of geometric shapes. These geometric shapes were placed randomly within two square areas so as to mask positive and negative cues of both types of discrimination problem.

Insert Figure 2 about here

There were 40 overlays, made up of four specimens of each of ten levels of visual noise. Levels of visual noise were established by varying the number of geometric shapes in each of the two square areas. Level 1, representing the absence of visual noise, had no shapes in either square area. Levels 2 through 10 and, 2,4,6,8,12,16,20,24, and 32 shapes in each square area.

All three kinds of stimuli were drawn on 5" x 8" sheets of colorless cellulose acetate plastic framed in cardboard for ease of handling. For each trial of the simple and evolving discrimination problems both the positive and negative cue appeared on a single sheet of plastic. The visual noise figures were stored in a box with ten compartments, so that the experimenter could quickly select a specimen of a particular level of visual noise. Using a Thermofax 66AG overhead projector, stimuli were projected onto a movie screen. Ss sat six feet from the screen. When the stimuli were projected onto the screen, the separation of the positive and negative cues was about three feet.

Subjects. Ss were 30 fifth graders drawn from two classrooms of a public school in Waltham, Massachusetts.[2] The mean age was 11-0, and there was a range from 10-2 to 12-0.

Procedure. Stimuli for the first trial of the simple discrimination were projected onto the screen, and *Ss* were told:

> "Look at the figure on your right. In this game that figure is correct. Each time try to tell me which side that figure is on -- right or left."

After each choice, *Ss* were told, "Good," or, "Not that time." As the correct side changed according to a random sequence, *Ss* were required to select correctly ten times. Then the E began to introduce visual noise. Starting at Level 2, the level of visual noise was increased by one after each correct choice, until the *S* made an error. If *S* reached Level 10, this level was continued until an error occurred.

When *S* made an error, this task was stopped and he was introduced to the everchanging discrimination. The stimuli for the first trial were projected onto the screen and the *S* was told:

> "Look at what you see on your right. What you see on your right is correct this time. But it will change a little each time. Pretty soon it won't look at all like what you now see on your right. Each time, try to tell me which side it is on. Sometimes it will be too hard for you, but don't worry; it gets too hard for everyone. If you don't know which side is correct, just make the best guess you can."

Ss received at least ten trials on this task without visual noise. Before visual noise was added, the last three choices had to be correct. Beginning at Level 2, the level of visual noise of the overlay was increased by one after each correct choice until an error occurred. At this point visual noise was reduced to Level 1 (no visual noise), until three correct choices were made. Then visual noise was added again. As before, Ss reaching Level 10 were given different examples of this level of visual noise until they made an error. This procedure was repeated until the first error after the 70th trial. During this task the basic everchanging stimulus series always advanced on each trial, regardless of S's response.

The total time required to run each S ranged from 25 to 35 minutes.

Results

Observation of Ss' behavior in the simple discrimination indicated that the visual noise was having the intended effect of making the problem more difficult. It was evident that the more the noise the longer Ss took to identify the correct cue and, with high levels of visual noise, latencies of response were as long as 15 seconds. However, almost all Ss could handle the highest noise levels on this task. Twenty-six of the 30 Ss responded correctly at least once at level 10. Ss seemed to fail only when the particular overlay of visual noise was an unusually effective mask of the stimuli of the discrimination. It was concluded that in a problem where exactly the same visual figure had to be located again and again Ss of this age could cope with maximal amounts of our visual noise scale.

On the evolving discrimination, however, Ss operated correctly only at lower noise levels. Each S made at least six errors capping sequences of correct choices at ascending levels of noise. The level of visual noise on the last correct trial before an error was taken as an estimate of the maximal level of noise at which the S could cope with an evolving discrimination. Individual mean maxima ranged from 2.5 to 8.4 with a mean of means of 6.3 and a standard deviaiton of means equal to 1.3. There were marked individual differences among the Ss in their ability to cope with the evolving discrimination through noise, but it was clear that Ss could cope with much less noise during performance of the evolving discrimination than they could during the simple discrimination.

Did Ss learn to handle the noise? Some Ss achieved progressively higher maxima during the task, as though learning or adaptation were taking place. Other Ss showed declining maxima, as though they were fatigued or bored. To test trend quantitatively, the average of the first three noise maxima for each S was compared with the average of his last three maxima. There was a slight trend towards higher maxima, not significant ($t = 1.61$; $p < .20$). It was our impression that this statistically neutral trend represented a positive learning trend balanced by an opposed negative trend brought about by fatigue. Usually, fatigue is not a factor in a task of this length, but our high noise trials were visibly quite demanding on the Ss. They often had to engage in prolonged and effortful study of the stimulus field before making their choice, and their remarks sometimes indicated that they found this wearisome and slightly unpleasant.

We alluded earlier to discontinuities in the evolving stimulus series. Periodically, one of the two shapes making up the positive cue and the negative cue would drop out. (See Figure 1) During the first ten trials of the evolving discrimination, when there was no noise, all Ss were consistently correct in their choices. However, Ss took much longer to make a response on trials where a shape which had been part of the positive cue dropped out completely. Later, when noise was present, long latencies and errors were common on this type of trial. At such points Ss were likely to say, "It's not there," or "Neither one is right."

An analysis of errors made on different types of trials confirmed the impression of uneven difficulty in the stimulus series. Trials where only one shape was left in the positive cue were considered "hard" trials; the trials immediately following these trials were also considered "hard" trials. Trials in which both shapes of the positive cue appeared in their largest form, and trials immediately following these trials were considered "easy" trials. For each S the numbers of errors on "hard" and "easy" trials were computed. Errors occurred much more often on "hard" than on "easy" trials ($t = 5.33$; $p < .001$).

Inspection of the data suggested that this relationship did not hold for all Ss. Therefore rates of error on "hard" and "easy" trials were examined for "good" Ss (those with the ten highest mean maxima) and "poor" Ss (those with the ten lowest mean maxima). "Good" Ss averaged 3.7 errors on "hard" trials and .5 errors on "easy" trials. This difference in error rates was highly significant ($t = 6.53$; $p < .001$). In contrast, "poor" Ss averaged 3.2 errors on "hard" trials and 2.8 errors on "easy" trials. This difference was not significant ($t = .39$; n. s.). For each "good" and "poor" S, the number of errors made on "easy" trials was subtracted from the number of errors made on "hard" trials. The resulting difference scores for Ss in the two groups could then be compared. For "good" Ss the mean difference score was 3.2, while for "poor" Ss, this score was only .4. Difference scores for the two groups differed significantly ($\underline{t} = 2.48$; $p < .05$). These results all lead to the conclusion that good Ss erred primarily on "hard" trials, whereas "poor" Ss erred almost as often on "easy" as on "hard" trials.

Some additional observations. During the course of the study, a number of signs testified to the difficulty of the noisy trials. The E, looking at the Ss, saw that they were experiencing difficulty through a number of indications -- long latencies, a posture of tense and active searching during the trial, remarks made by Ss. To elaborate such observations, ten further Ss were drawn from the same grade of another school and were administered the task with an observer present who made a stopwatch record of time to respond on each trial, and who noted informal impressions of Ss behavior during and between trials.

The stopwatch records gave some quantitative estimate of a trend which had been fairly obvious in the preceeding work. Each level demanded more and more time for the S to form his choice. For the ten Ss, mean choice times, in seconds, for levels 1-10 were 2.2, 3.1, 3.7, 4.0, 5.0, 5.7, 6.0, 5.6, 6.7, and 7.8.

The latency trend derived from the ten Ss is not statistically significant, but it is our belief that this is due to the great variability of the latency figures. We would suggest that the prolongation of choice under noise is "there". Certainly, during the larger preceding study, it was the E's strongest casual impression of the effects of the noise on the Ss.

The informal observation included notes on fidgeting and restlessness among the Ss. Ss, particularly the boys, would be quiet and somewhat tense during a trial, sitting leaning forward in their chairs, searching the window. Between trials, there would be unusually high restlessness and motor discharge, perhaps simply because the motor restraint during the trial cramped the Ss' muscles. Other evidence, to be discussed below, suggests that this cyclical pattern of motor restraint and motor discharge may support the performance of the Ss during the noisy trials and may even be necessary to it.

Discussion

The limits procedure was tried in an effort to develop a more efficient technique for the study of the effect of noisy cue conditions on problem-solving. The problem-solving was pitted against a series of noise levels, with time within a single session for six or seven tests for noise maxima. The task did have a quality different from those previously used to study cue variation during learning because it sought to find the S's limit. For some Ss, if not all, the task introduced a feeling of stress or fatigue not typical of experimental problem-solving or procedures and only some further exploration will indicate how useful the task can be. Nevertheless, these preliminary results seem to have some theoretical interest.

Our evidence suggests that without noise all Ss could make correct choices on the constant discrimination and on the easy or hard trials of the evolving discrimination. But the noise, in effect, converted the differential difficulty of correct choices (reflected, to casual observation, in choice latencies) into a differential incidence of errors. It seems intuitively obvious that this would be so, that visual noise would have this effect, but the rational basis of this intuition is not obvious in traditional terms. Traditionally, perception is supposed to come before thought (here, the determination of choice) and be apart from it.

The noise load in itself did not throw off the Ss: almost all Ss could choose correctly on the constant discrimination at level 10. The load of the evolving discrimination did not throw off the Ss: all Ss could track the evolving discrimination without noise. It was the conjunction of noise and choice which produced errors. Perhaps there is a tradeoff between perceiving and choosing in this situation. There is now a widespread conclusion that perception involves a sequential information-processing activity which is, essentially, thought (Luria, 1966; Neisser, 1966; Piaget and Inhelder, 1969) and that the human capacity for such information-processing is limited (Miller, 1956). Presumably, some components of what we commonly call perception and thought must share this limited capacity and, thus, a load on one can take away from the load that can be placed on the other.

At least a part of what is above called 'load' may consist in real time requirements. The most obvious effect of noise on any given trial is to extend the S's study of the stimulus display in order to locate his choice stimuli. The S does not perceive his choice cues instantaneously as figure-against-ground as is the case with noiseless cues. Time extension could amount to time overload. There may be a restrictive time span for the assembly of informational elements for conjoint determination of choice which is analogous to, or perhaps exactly the same as, the span of short-term memory (White, 1969).

We observed a cyclical pattern of motor restraint during the trials and motor discharge between the trials in a few of the Ss. This may be an index of a supportive mechanism. There is evidence suggesting that in older children and adults there may be a problem-solving mode, a special psychophysiological state with distinctive characteristics, which may serve to protect cognitive operations as they extend over time. That there is a special state during problem-solving is indicated by a miscellany of psychophysiological studies of problem-solving (Germana, 1968; Elias and White, 1969; Elias, 1970). It has been suggested that problem-solving may be protected by gradually rising gradients of arousal reflected in EMG and pupillary dilation records (Malmo, 1965; Beatty and Kahneman, 1965). At the same time, there has been repeated evidence indicating that Ss who show motor restlessness during a task (Duffy, 1932) or who are characteristically hyperkinetic (Kagan, Moss, and Sigel, 1963) have difficulty with problem-solving. It is possible that restlessness tends to dissolve the problem-solving mode. The S expends effort to sustain the quiescent state during the critical time of the trial and then "catharts" restrained motor behavior between trials. As a task increases in complexity, the demands on the S to sustain the problem-solving mode over time may exceed his capacity and thus, in one sense, his attention span.

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Footnotes

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Table 1

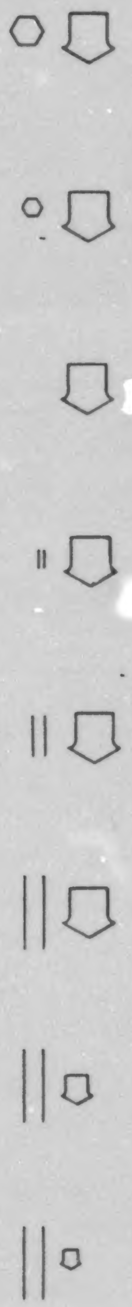
Comparisons of Control, Varying-Position, and Late-Varying-Position Conditions at Three Grade Levels

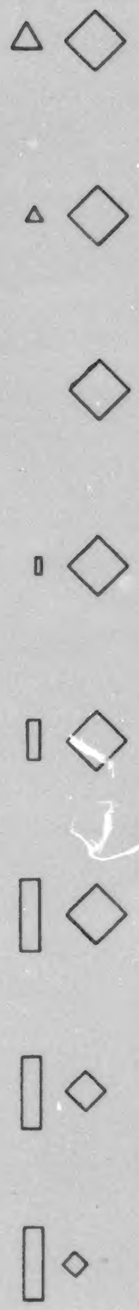
Grade	Condition					
	Varying-Position		Late-Varying-Position		Control	
	N	Trials to 9/10	N	Trials to 9/10	N	Trials to 9/10
Kindergarten	20	33.6	20	35.2	20	44.4
Second Grade	20	25.9	20	32.9	20	33.2
Third Grade	20	24.5			20	12.2

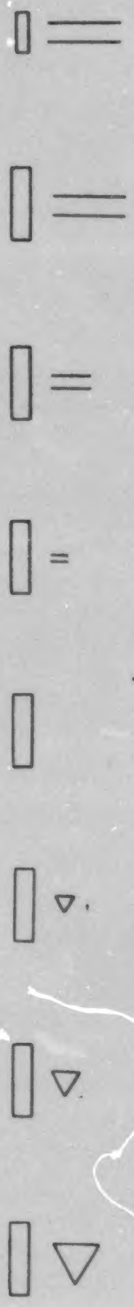
Figure Captions

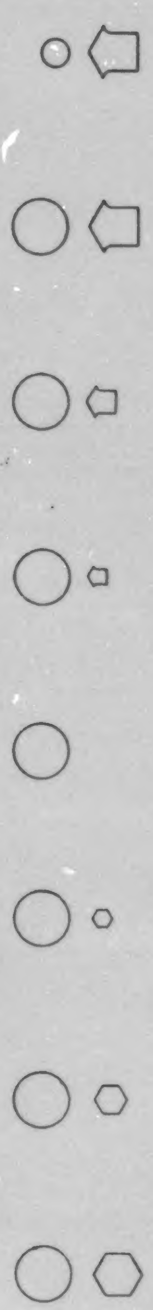
Fig. 1. The everchanging stimulus series. Figures seen on Trials 1-8 (two left columns) and Trials 41-48 (two right columns).

Fig. 2. A trial of the everchanging stimulus series, with different levels of visual noise added: (a) Level 1 (no visual noise) (b) Level 4 (c) Level 10.









(a)

(b)

(c)

Developmental Trends in the Effects
# of Noise on Problem Solving

Richard Scott Mansfield

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Abstract

Earlier research has shown that there is a development with age in the ability to attend selectively. Selective attention may be viewed as coping with irrelevant stimulus variation or noise, during problem solving. The purpose of the present study was to test for the development of the ability to cope with noise in problem solving. Two tasks: an auditory task and a visual task, were used to test the ability. As a test of general intelligence, the Peabody Picture Vocabulary Test was also administered. There were 30 kindergarten and 30 second grade subjects: 15 boys and 15 girls at each grade level.

The visual task tested the ability to cope with visual noise in three types of problems: the first a discrimination with constant position of presentation of cues, the second a discrimination with varying position of presentation of cues, and the third a relational problem. In all problems the positive and negative cues appeared on the right and left sides of a movie screen. Both types of discrimination problems required the subject to point to a constant pair of shapes, and the relational problems required the subject to point to larger, thinner, or flatter pairs of shapes. On all problems the subject first learned to point correctly in the absence of noise. Visual noise, irrelevant shapes superimposed over the cues, was then added in graduated increments on successive trials, until the subject made an error.

The auditory task tested a subject's ability to detect a target message through different intensities of noise. The task required the subject repeatedly to point to one of eight familiar objects drawn on

a sheet of paper before him. Subjects pointed according to the instructions of a signal voice, in the absence of noise. The noise, a mixture of four voices talking together, was then superimposed over the signal in graduated increments on successive trials, until the subject made an error. Next, the noise level was set high enough to preclude perception of the signal, and then lowered in graduated increments, until the subject pointed correctly. The procedure was repeated five times at each of three levels of signal volume.

For the visual task the results showed that thresholds for noise were a function of the type of problem. Kindergarteners had their highest thresholds on the discriminations with constant position. Thresholds were slightly lower on the discriminations with varying position. The lowest thresholds were on the relational problems. Second graders performed at maximal levels on both types of discrimination problems, but at significantly lower levels on the relational problems. The second graders were consistently superior to the kindergarteners. At each grade level subjects with higher IQs performed better than subjects with lower IQs. However, at the kindergarten level the superiority of the high-IQ group was more marked on the discriminations than on the relational problems, while at the second grade level the superiority of the high-IQ group was apparent on the relational problems, but not on the discriminations.

Thresholds for noise on the auditory task were also higher for second graders than for kindergarteners. At the kindergarten level high auditory performance was associated with high visual performance. But at the second grade level there appeared to be no relationship between auditory and visual performance.

The results were discussed in terms of the abilities required by the visual and auditory tasks. It was suggested that the abilities required on the visual task were memory for shapes, systematic scanning, and inhibition of impulsive responding. The auditory task seemed to require the ability to sustain attention to the signal voice, the ability to determine when signal words were being presented, and the ability to make use of the set of response alternatives.

Some technical problems in the visual and auditory tasks were discussed, and a revised methodology was proposed. Finally, directions for future research were suggested.

Background of the Study

The selection of sensory information from the environment poses a central problem for researchers in perception, cognition, and learning. Organisms normally are exposed to a constant welter of stimulation from different sensory modalities. Yet at any given time they are able to focus on only a selected portion of this stimulation. This focusing, or selective attention, is a way of allocating cognitive resources to facilitate analysis of information. The processes underlying selective attention are necessarily complex, for we are able to attend to highly specific kinds of stimulation within one sensory modality. At a symphony, for example, it is possible to attend to the music of one instrument, even though many other instruments may be playing simultaneously. Examples of selective attention in other sensory modalities are also plentiful. In a broader sense, selective attention may be viewed as a process allowing the separation of relevant from irrelevant information. Selective attention is thus a necessary precondition for the application of higher-level cognitive processes, and may be a crucial component of intelligence, or problem-solving ability.

During the ascendancy of behavioristic psychology, there was little interest in selective attention. As an unobservable, internal process, it was not considered worthy of study. However, a number of experiments in discrimination learning demonstrated that animals sometimes respond to only one dimension of a stimulus, and also that this dimensional responding can over-ride learned associations between stimuli and responses. The reader is referred to reviews of this literature by Mackintosh (1965) and by Fellows (1968). To accommodate these results, stimulus-response theorists proposed various processes allowing for selection of stimulus information. While some theorists (Spence, 1940; Wyckoff, 1952; Kurtz, 1955) attempted to explain the selection in terms of overt, orienting responses, other theorists realized that internal, unobservable processes must be at work. Among the hypothetical processes proposed were: attention to stimulus dimensions (Zeaman and House, 1963), stimulus coding (Lawrence, 1963), mediation (Kendler and Kendler; 1962, 1966), and stimulus analyzer selection (Sutherland; 1959, 1964). These hypothetical processes permitted some theorists to maintain a stimulus-response theory of learning. However, this theory has not been very useful in explaining the internal processes underlying learning in human subjects.

Stimulus Selection in Perception and Cognition

Recently, however, there has been a widespread revival of interest in the internal mental processes ignored by the behaviorists. The processes responsible for perception, recognition, and memory are being actively studied. And the problem of how organisms select stimulus information is again a popular concern. Selection has been demonstrated at many levels of perception and cognition.

Cognition operates through a hierarchy of processes. At the lowest levels are elementary feature analyzers responsible for perception. At higher levels are the processes responsible for focused attention. At still higher levels are processes for the coding, memory, and retrieval of information. The higher mental processes required for problem-solving are near the top of the hierarchy. This view of cognition is of course oversimplified, but the notion of hierarchically organized processes appears established. Psychologists have found selection of information at every level of processing they have studied. Some examples of selection at different levels will be outlined below.

Researchers in neurophysiology have demonstrated selection at very low levels of the visual system. For example, Lettvin and his colleagues (Lettvin, Maturana, McCulloch and Pitts; 1959) recorded the activities of fibers in the optic nerve fibers of unanesthetized frogs while presenting various visual stimuli. They found that each fiber had its own "receptive field," or region of the retina where stimulation would produce some activity in the fiber. These fibers proved to be quite selective, in terms of the kinds of stimulation appearing in their receptive fields which would produce a response. For example, one type of fiber, termed a "net convexity detector," responded if a small dark object entered the receptive field and continued firing as long as the object remained there. Other fiber types responded to sustained contrast, moving edges, and net dimming.

Hubel and Wiesel (1959, 1962; Hubel, 1963) also found evidence of selection in the visual system. Recording from cells of the cat's visual cortex, they found cells that responded to the orientation of stimuli on the retina. Some of these cells had what Hubel and Wiesel called "simple" fields. Such cells responded most strongly to a particularly oriented edge occurring at a particular position within the receptive field.

Other cells, with "complex" fields, were insensitive to the exact position of the edge within the receptive field, provided that a critical orientation was maintained. Like the cells in the optic nerve of the frog, these cells in the visual cortex of the cat effectively select information from incoming stimuli.

Visual pattern recognition requires analysis at a slightly higher perceptual level. Selection in pattern recognition has been required in studies where visual noise is added to patterns which must be recognized under tachistoscopic presentation. This literature is reviewed by Webster (1966). Also in the area of pattern recognition, selection has been demonstrated in the studies of visual search by Neisser and his associates. These experiments are reviewed by Neisser (1966, pp. 68-70). Typically, subjects are required to scan 50-line lists, each containing a single target letter at an unpredictable position. In scanning the lists, subjects report that they do not see individual letters; the list is a blur from which the target letter stands out. Since the subjects find the target letters, all the letters in the lists must undergo at least some lower-level analysis. But by some selective process the target letters are singled out for a more detailed analysis resulting in their ultimate perception.

At a higher level than pattern recognition, much selection of information occurs through active, focal attention. Visual focal attention, as measured by eye movements, has been shown to influence learning (Wyckoff, 1952; White, 1966). But focal attention has more often been studied in the auditory modality, by requiring subjects to "shadow" or repeat a message presented to one ear, while another message is simultaneously presented to the other ear. This literature is reviewed by Neisser (1966, pp. 206-212). While shadowing one message, subjects may become aware of certain kinds of information from the unshadowed message. And under some conditions they inadvertently switch their shadowing temporarily from one message to the other. These phenomena have inspired much theoretical debate about the nature of selective auditory attention.

A group of neurophysiologists (Hernandez-Peon, Scherrer, and Jouvet; 1956) have possibly discovered a neurological manifestation of focal attention to one sensory modality. Recording from the cochlear nucleus of the cat, they found that the electrical activity produced by a sound was sharply reduced when the cat was presented with a visual or an olfactory stimulus. The authors interpreted their results in terms of a shift in attention. But this interpretation must be regarded with caution, since it has been disputed by other neurophysiologists (Hugelin, Dumont, and Paillas; 1960).

Above the level of focal attention, selection also occurs in processes related to memory. The selective nature of memory requires no examples. But the importance of selection in the encoding of information has recently been demonstrated in studies of the effect of preparatory set on the recognition of briefly presented visual cues. Apparently, a preparatory set facilitates recognition if it permits the subject to encode the stimulus selectively (Harris and Haber, 1963; Haber, 1964a,b).

Selection also occurs in problem-solving, when higher mental processes are used. Bruner, Goodnow, and Austin (1956) studied strategies in difficult concept-attainment problems. The most efficient strategies were called "focusing strategies," because they permitted consideration of the smallest amount of relevant information necessary for solution.

This brief review has shown that selection occurs at many levels of perception and cognition. It is by no means assumed that the processes responsible for selection are similar in all the cases cited. But selection usually implies a separation of relevant from irrelevant information.

The Role of Noise in Cognitive Problems

It was proposed earlier that at the level of focal attention the ability to separate relevant from irrelevant information may be a crucial component of intelligence or problem-solving ability. Indeed, irrelevant information or noise is built into most cognitive problems. A very broad definition of noise is assumed here: noise is any aspect of the problem that interferes with the straightforward application of the cognitive operations necessary for solution. When noise is part of a problem, solution requires two abilities: the ability to cope with the noise by determining the problem's relevant aspects, and the ability to apply the required cognitive operations to these relevant aspects. While solution of the problem implies the presence of both abilities, failure may mean only that the subject is deficient in coping with the noise. With a reduction in the amount of noise, the subject might be able to apply the required cognitive operations.

This argument has implications for many developmental studies of cognitive ability. Psychologists have often interpreted younger children's failure on a particular task as evidence of a deficiency in some cognitive ability. But it is possible that in many cases younger children's failure stems only from an inability to cope with noise. This interpretation would explain the unreliability of many age-related findings. Slight procedural changes, having no obvious effect on the required cognitive operations, may sufficiently alter the amount of noise in the problem to bring about different levels of performance.

The results of a number of developmental studies using different cognitive tasks, suggest that the ability to cope with noise may determine performance. Levin and Hamermesh (1967) observed that in laboratory studies of matching and oddity learning children often perform much more poorly than on conceptually similar tasks from the Stanford-Binet. The authors hypothesized that procedural and instructional variables are important determinants of children's performance on matching and oddity learning tasks. Testing this hypothesis, they required one group of subjects always to touch the sample stimulus shape before choosing one of the alternatives. This condition was intended to force the subject to look at the sample cue. Another group was given instructions emphasizing the possibility and desirability of being correct on every trial. These instructions were intended to counteract the tendency to adopt position-based strategies leading to only partial reinforcement. Both groups performed significantly better than a control group receiving neither of these instructions. For both experimental groups the effect of the instructions may have been to reduce the noise in the experimental situation.

The ability to cope with noise may also affect performance on Piagetian conservation tasks. Bruner, Olver and Greenfield; 1966) have suggested that younger children's failure on tasks testing conservation of volume is due to distraction by a perceptually salient aspect of the transformed stimuli. An irrelevant perceptual cue may be regarded as a form of noise. Bruner found that young children gave more responses indicating conservation when the transformed stimuli were screened, so that the irrelevant perceptual cue was not available. Thus screening obscured a kind of noise in the experimental situation.

There is evidence that coping with noise is also important in the conservation of concepts of quantity. Whereas Piaget (1952) had placed the acquisition of this type of conservation between the ages of six and seven, Mehler and his co-workers (Mehler and Bever, 1967, 1968; Bever, Mehler and Epstein, 1968) have recently found evidence for conservation of quantity as early as 2 years, 4 months. Specifically, they found evidence for a decline in conservation between ages 2-4 and 3-9, followed by an increase between ages 3-9 and 4-7. Interpreting these results, Mehler and Bever (1968) proposed that the capacity for conservation of quantity is present in 2-year-olds, but subject to more general limitations of attention and memory. To overcome these limitations, the child forms perceptual generalizations (e.g., The longer row has more circles in it.) which work in a majority of instances. But when the child discovers that these perceptual generalizations fail in critical cases, as in the tasks used to test conservation of quantity, he is ultimately impelled to integrate them into a system that includes both the basic logical capacities and the perceptual generalizations. Very young children show conservation because one source of noise, the perceptual generalizations, is not yet effective.

In other developmental experiments the complexity of instructions for cognitive tasks has been varied, so that in effect, the tasks have been presented under varying conditions of noise. Huttenlocher and Strauss (1968) reported two experiments in which children were required to place a colored block on a ladder containing one or two other, different colored blocks in fixed positions. The resulting sequence of blocks had to correspond to some verbal statement describing the sequential relationship. When the mobile block corresponded to the grammatical subject in the verbal statement, children made fewer errors and took less time than when that block corresponded to the grammatical object. In the latter condition subjects had to transform the statement, so that the mobile block became the grammatical subject.

A subsequent experiment (Huttenlocher, Eisenberg and Strauss; 1968) required subjects to place a mobile truck adjacent to a fixed truck, so that the positions of the trucks would conform to active and passive statements describing which truck was pushing or pulling the other truck. For active statements, as for relational statements in the previous experiments, it was easier to place the mobile truck correctly when it was the grammatical subject than when it was the grammatical object. For passive statements, on the other hand, it was easier to place the mobile truck correctly when it was the grammatical object. For both active and passive statements performance was poorer if the statement had to be transformed so that the mobile truck would correspond to the grammatical subject.

In another experiment Zern (1970) used a verbal exercise in which essentially the same question was asked in different ways, so that the number of mental steps required to answer the question was varied. In effect, he varied the amount of noise in the question. The question always asked whether a given number was odd or even. Response latency was found to be a function of the number of mental steps required to decode the question. The tendency to operate according to a "mental step" hypothesis was equally apparent in children of all ages ranging from 4 to 12.

Zern's study and the studies of Huttenlocher and her co-workers found that varying the complexity of the instructions increased the difficulty of problems. In one sense complex instructions constitute a form of noise. Thus adding noise increased problem difficulty. The Levin and Hamermesh study, showing that instructional changes facilitate matching-to-sample performance and oddity learning, and the studies using perceptual screening to demonstrate conservation in young children, all suggest that decreasing the noise in an experimental situation improves the performance of young children. The implications are that the amount of noise in a problem is an important determinant of performance, and that the ability to cope with noise develops with age.

Developmental Trends in Selective Attention

If the ability to cope with noise is important in problem-solving, it would not be surprising to find that improvement in this ability had broad implications for cognitive development. Werner's (1961) theory suggested an important role for selective attention in cognitive development. Werner suggested that perception is initially global and becomes capable of differentiation only with development. Percepts from different sensory modalities are at first undifferentiated. Eventually, however, fine discriminations within a sensory modality become possible.

Inspired by Werner's theory, Witkin and his co-researchers (Witkin, Lewis, Herman, Machover, Meissner, and Wapner, 1954; Witkin, Dyk, Faterson, Goodenough, and Kay, 1962) defined a cognitive dimension: field dependence-independence. This dimension was measured by tasks requiring perceptual field articulation. Field-independent subjects, in contrast to field dependent subjects, showed less global and more analytic responding on a variety of cognitive tasks. Furthermore, with development, children were found to become more field-independent, and hence more analytical on perceptual and cognitive tasks. To the extent that field articulation implies the ability to attend selectively to certain cues and to ignore other cues, these findings are suggestive of developmental changes in selective attention. Further evidence for development in selective attention comes from diverse areas of research. Some of these areas are considered briefly below.

Incidental learning. Some researchers have used incidental learning studies to assess the ability to attend selectively. Typically, subjects are required to learn something about relevant cues when irrelevant cues are also present. Usually, there is also a simultaneous "distractor" task to insure an overload of stimulation. Hagen and Sabo (1967) hypothesized that under these circumstances, older children, with a greater ability to attend selectively, would be able to inhibit attention to the irrelevant cues, so as to be able to learn as much as possible about the relevant cues. In contrast, younger children, unable to focus attention exclusively on the relevant cues, would continue to learn about the irrelevant cues. Thus the ratio of central to incidental material learned would increase as age increased.

Testing this hypothesis, Maccoby and Hagen 91965) and Hagen (1967) found that recall of central material increased regularly with age, while recall of incidental material did not. Hagen's study also found correlations supporting the developmental hypothesis. He found positive correlations between recall of central and incidental material for children in grades 1, 3, and 5, but a negative correlation at grade 7. His explanation was that in younger children the same factors affecting recall of the central material affected recall of the incidental material, while in older children performance on the central task was a function of the degree to which they could inhibit attention to the incidental cues.

The interaction between age level and central-incidental recall was replicated by Hagen and Sabo (1967), who showed that the increasing proportion of central to incidental material recalled was also apparent in ninth graders. These authors also demonstrated that differential recall rates for central and incidental material could not be attributed to different rates of memory loss for the two types of material. The recall rates were the same, whether central or incidental material was reported first.

Druker and Hagen (1969), also using an incidental learning experiment, found evidence that the greater tendency of older children to focus on the central and incidental cues led to a decline of incidental recall in older children, but not in younger children. A post-test questionnaire, administered to all subjects, showed two response tendencies clearly related to age: focused visual scanning and verbal labeling. The authors proposed that these skills were responsible for the older subjects' better ability to focus on the central material.

Several other studies have found decreases with age in the relative amount of incidental learning. Crane and Ross (1966) studied attention to cues of relevant and irrelevant dimensions in a visual discrimination problem. Cues from both dimensions were made redundant during an overtraining period, and then a second learning problem was administered. In comparing second and sixth graders, it was evident that the sixth graders had been focusing attention more exclusively on the dimension-relevant aspects, while the second graders' attention was more global. A study by Siegel and Stevenson (1966), using a discrimination learning task with central and incidental components, showed an increase in incidental learning between ages 7 and 12, and a decline between ages 12 and 14. The researchers concluded that older children tended to disregard the irrelevant stimuli. A subsequent study by Siegel (1968) showed that 14-year-old children were better able to inhibit attention to constant irrelevant cues than to changing ones in a discrimination learning task.

All these studies using incidental learning suggest an increase with age in the ability to attend selectively. But, as an index of selective attention, the proportion of central to incidental material learned is rather crude. With this proportion as a measure, selective attention is partly a function of material not learned. Moreover, the incidental learning experiments assume an overload of incoming information. The overload necessitates a selection. But the assumption of an overload may not be valid for all subjects. Highly intelligent subjects, or subjects with eidetic imagery, might be able to process all incoming information. For such subjects the proportion of central to incidental material recalled would not constitute a valid index of selective attention. Furthermore, the incidental learning technique reveals little about the processes by which selection is accomplished. Possible processes include focused visual attention, systematic scanning strategies, and encoding and rehearsal practices. To determine which processes are at work in a given experimental situation, a more direct method of measuring selective attention is needed.

Visual search. Other evidence of development improvement in visual selective attention comes from studies of visual search behavior. Neisser's work in this area, with adult subjects, has already been mentioned. In a study by Gibson and Yonas (1966) second, fourth and sixth graders and college sophomores were required to search for one or two target letters in lists of letters varying in visual confusability. Search time decreased with age, and a highly confusable visual context increased search time at all age levels. No interaction was found between age level and degree of confusability of context. It had been hypothesized that with a highly confusable context younger subjects' search time would be increased much more, relative to that of older subjects. For the younger subjects were presumed to be less familiar with letters and their distinctive features. However, it is possible that even the youngest subjects were so familiar with letters that highly confusable contexts disrupted their performance no more than that of older subjects. In any case, the superiority of older subjects on the visual search tasks suggests an improvement with age in the ability to select relevant from irrelevant information.

Pattern recognition. One tachistoscopic study of recognition suggested developmental changes in attention. Munsinger and Gummerman (1967) studied the effect of visual noise on the identification of tachistoscopically presented random polygons. Second graders, fifth graders, and college adults were required to identify high and low variability forms with grids of noise superimposed. The grids were either systematic or random in the distribution of lines along the X and Y coordinates, and were of either low or high density. Identification of forms was easier when the noise was of low density and when it was systematic. Under all conditions the adults were superior to the fifth graders, who in turn were superior to the second graders. There was also an interaction between age level and density of noise, with the superiority of adults over children being most marked under low-density noise. Finally, it was found that children could more easily learn to extract signal from systematic noise than from random noise. Thus the study demonstrated an improvement with age in the ability to identify briefly presented patterns obscured by noise. To the extent that noise had to be ignored, selective attention was required.

Selective listening. Developmental changes in selective attention have also been studied in the auditory modality. Maccoby and Konrad (1967) required children aged from 5 to 12 years to identify one of two simultaneously presented auditory messages. In some experimental conditions a visual signal, two seconds before the presentation of the auditory messages, indicated which of the two messages was to be identified. In other conditions the signal occurred after the presentation of the messages. There was an improvement with age in the ability to report accurately the target message. However, it was not found that the older children's better performance could be traced to any greater ability to maintain set for the target message. Children of all ages studied improved their performance with a preparatory signal when listening for two-word phrases, and the amount of improvement was similar for all age levels. When listening for single words, the oldest group did not improve performance with a preparatory signal, whereas younger children did. The investigators concluded that the older children were better able to do without a preparatory signal.

It was not entirely clear how preparatory signals facilitated performance. The advantage was not in allowing the subject to orient his ears, since the signal was just as effective when both messages came over a single loudspeaker as when they came over separate speakers. Nor did the advantage of the preparatory signal depend upon the familiarity of the stimuli, upon their sequential probability, or consistently upon the age of the subjects. The authors rejected the hypothesis that the effect of set was to reduce the burden on immediate memory for the messages. If this hypothesis were true, the advantage of the preparatory signal would have been greater when the messages were longer, less familiar, and of lower sequential probability. But the preparatory set improved performance no more under these conditions than under control conditions. And despite a moderate increase in memory span across the age levels studied, the magnitude of the advantage of the preparatory signal did not decrease with age. As an alternative explanation, the researchers suggested that the preparatory signal allowed a shifting of attention to the desired elements of a complex stimulus. If this explanation was correct, then subjects of all ages studied had the ability to focus attention to some degree. And the development of the ability was commensurate with the development of other abilities, responsible for identification of the messages without the preparatory signal.

Varying cues. A final source of evidence for developmental changes in selective attention comes from studies using varying cues. A number of studies have shown that younger children are poorer than older children in coping with varying stimuli. Gollin studied tactual discrimination of forms made by patterns of tacks on a wooden base. In one study (Gollin, 1960) he found that first, second, and third graders were only slightly poorer than adults at deciding whether two of these forms were the same or different. But when noise was added to the forms, through the addition of larger tacks, which had to be disregarded in making judgments, adults were able to ignore the noise and maintain good performance, while children were not. In other studies using this tactual discrimination task (Gollin, 1961) younger children were poorer than older children at learning to discriminate when there were extraneous tacks.

Other evidence of older children's superiority in coping with problems involving varying cues comes from discrimination learning studies (Walk and Saltz, 1965; White, 1966; Brown, 1969). White (1966) introduced three kinds of stimulus variation into a standard discrimination learning problem: variation of the positive cue, variation of the negative cue, and variation of the positions where the cues were displayed. The results of the study, in which the different problems were given to young children of different ages, suggested the existence of an age-shift, occurring between the ages of five and seven, in the ability to cope with the stimulus variation. Before the age shift, stimulus variation impeded learning, while afterwards, stimulus variation had either a neutral or a facilitating effect. Walk and Saltz (1965) and Brown (1969) also found evidence for an age-shift in the ability to cope with cue variation. However, they did not replicate the order of difficulty for the cue variation and control conditions that White had found for older children. Furthermore, a recent attempt failed to replicate the age-shift in the effects of the varying position condition (White and Mansfield, 1969). Thus the discrimination learning studies produced unreliable results.

But there are other disadvantages to using discrimination learning rate as a baseline against which to measure the ability to cope with stimulus variation. Each subject can be tested only once, and under only one condition of stimulus variation. For these reasons a different technique was needed to investigate developmental changes in the ability to cope with stimulus variation.

Visual Noise in Problem Solving

White and Mansfield (1969) developed a technique in which subjects were required to make response choices based upon differences in a pair of visual cues. Graduated amounts of visual noise were added to two discrimination tasks, one with constant cues, and one with evolving cues. An ascending method of limits procedure, to be described in detail later, measured a subject's capacity to cope with a series of visual noise levels. Thirty fifth graders were able to cope with high levels of visual noise when the relevant cues were constant. But in the evolving discrimination performance was disrupted by moderate levels of visual noise. Poorer performing subjects were disrupted by middle levels of noise, regardless of the amount of trial-to-trial change in the positive cue. Better performing subjects, however, were able to cope with high levels of visual noise, except at times of large change in the positive cue. The researchers concluded that the greater the amount of "cognitive work" demanded by the underlying discrimination task, the greater was the potentially disruptive effect of visual noise.

Purposes of the Present Study

The results of the fifth grade study suggested that superimposing visual noise on visual choice response tasks provided a satisfactory method for studying the ability to filter out irrelevant information during problem-solving.

The main purpose of the present study was to determine whether there are developmental changes in the ability to cope with visual noise. As was previously mentioned, Munsinger and Gummerman (1967) found developmental changes in the ability to identify tachistoscopically presented forms in the presence of visual noise. In the present study the emphasis was on problem solving, rather than pattern recognition. No time limits on viewing the stimuli were imposed, and the target and noise figures were very similar in appearance. A second purpose of the present study was to test whether the effect of problem difficulty on visual noise threshold would be different for kindergarteners and second graders. Third, the study investigated the relationship between IQ and the ability to cope with visual noise on tasks of graded difficulty. Finally, the study tested whether visual noise threshold was related to auditory noise threshold, as measured by an auditory task.

First, it was predicted that on the visual task older children would perform better than younger children, regardless of problem difficulty. Second, an interaction was expected between the effects of age and problem difficulty. Differences between average performance levels on problems of varying difficulty were expected to be greater for younger children than for older children. There were two assumptions underlying this prediction. The first was that visual noise was potentially most disruptive when the underlying problem demanded high amounts of cognitive work. The second assumption was that the amount of cognitive work demanded by a problem was not the same for children of different ages. For older children it was likely that none of the underlying problems entailed much cognitive work; hence visual noise was expected to produce only small differences in performance on the problems, although they were graded in difficulty. For younger children, however, it was likely that the problems of varying difficulty did entail different amounts of cognitive work. Therefore, younger children's scores were expected to be more divergent than older children's on these problems.

Another similar hypothesis was that there would be an interaction between the effects of IQ and problem difficulty. The effect of problem difficulty was expected to be less apparent in high-IQ than in low-IQ children. The reasons for this hypothesis were similar to the reasons outlined above for the prediction of differential performance of older and younger children.

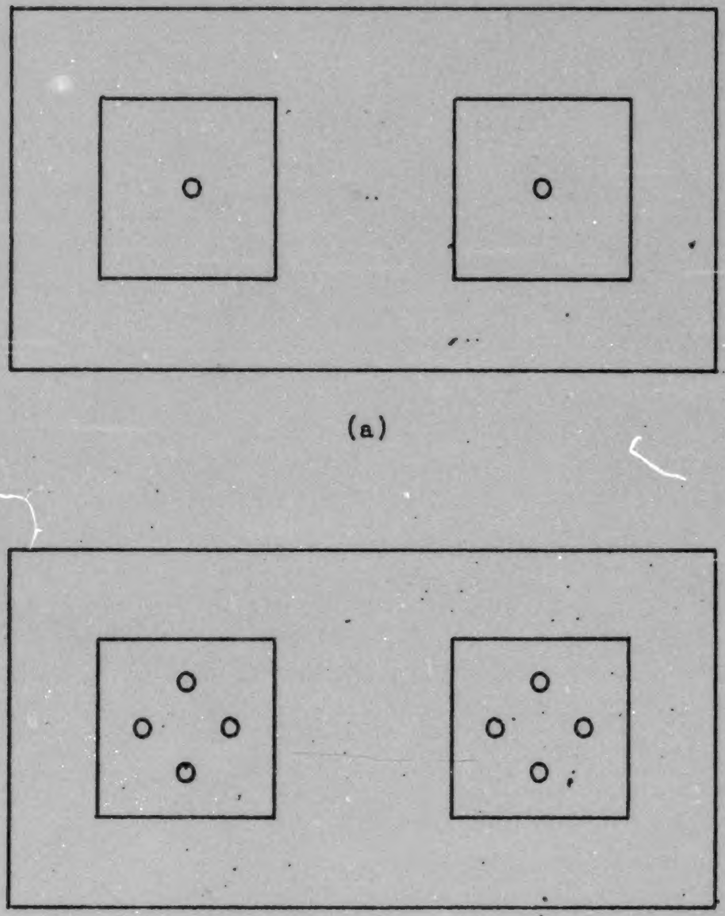
Finally, it was predicted that the ability to cope with visual noise would be related to the ability to cope with auditory noise on an auditory task. This prediction assumed that some central processes facilitate selective attention across sensory modalities.

Method

Three tasks were administered in separate sessions, always in the same order: a visual task, the Peabody Picture Vocabulary Test (PPVT), and an auditory task. The PPVT was administered in standard fashion, according to the instructions of the test manual (Dunn, 1965). The method and procedure for the visual and auditory tasks are presented separately below. Subjects were 30 kindergarten and 30 second grade children from an elementary school in Newton, Massachusetts. The school drew students chiefly from working class and lower middle class families. To facilitate analysis of possible sex differences in performance, equal numbers of boys and girls were tested at each grade level.

Visual Task

The visual task tested the ability of kindergarten and second grade children to cope with visual noise in three types of problems varying in difficulty. In all three types of problems the subjects made response choices between pairs of cues displayed on a large movie screen. The easiest type of problem was a discrimination with constant cues, which always appeared in the same two positions on the right and left side of the screen. These positions were the centers of two square areas in which visual noise might appear (See Figure 1). On successive trials the positive cue appeared on the right or the left according to a random sequence. The second type of problem was also a discrimination with constant cues, but the cues might appear in any of four positions within the noise fields. The location of the cues within the noise fields



(a)

(b)

Figure 1. Positions where cues may appear in noise fields: (a) in discriminations with constant position of cues, and (b) in discriminations and relational problems with varying position of cues. The squares are noise fields and never appear on the screen. The circles are positions where cues may appear.

was unpredictable. The third type of problem, with cues changing from trial to trial, required the subject to choose on the basis of some relation between the two cues. In three relational problems the larger, thinner, and flatter shapes were respectively correct. Again, the position of the cues within the noise fields was unpredictable. In all three types of problems the subject was first taught to choose correctly in the absence of visual noise. Visual noise was then superimposed in graduated increments after each correct choice, until the subject made an error. Repeated runs of ascending noise increments yielded several estimates of a subject's capacity for visual noise on each type of task.

Stimuli. Stimuli for the visual task were of two general types: stimuli making up the positive and negative cues for the three types of problems, and stimuli making up the visual noise.

The stimuli making up the positive and negative cues in all three types of problems had the same general design: each cue consisted of two line drawings of shapes, connected by a short line (See Figure 2). In the discrimination problems each cue consisted of two different shapes, selected from a library of eight such shapes. In no discrimination did a shape appearing in the positive cue also appear in the negative cue. Six discrimination problems were administered to each child: three with constant position of cues and three with varying position.

There were three relational problems. The first was a size discrimination procedure. Both the positive and negative cues were a constant pair of shapes differing only in size; the larger cue was always the positive one. Since the cues might appear in any of four

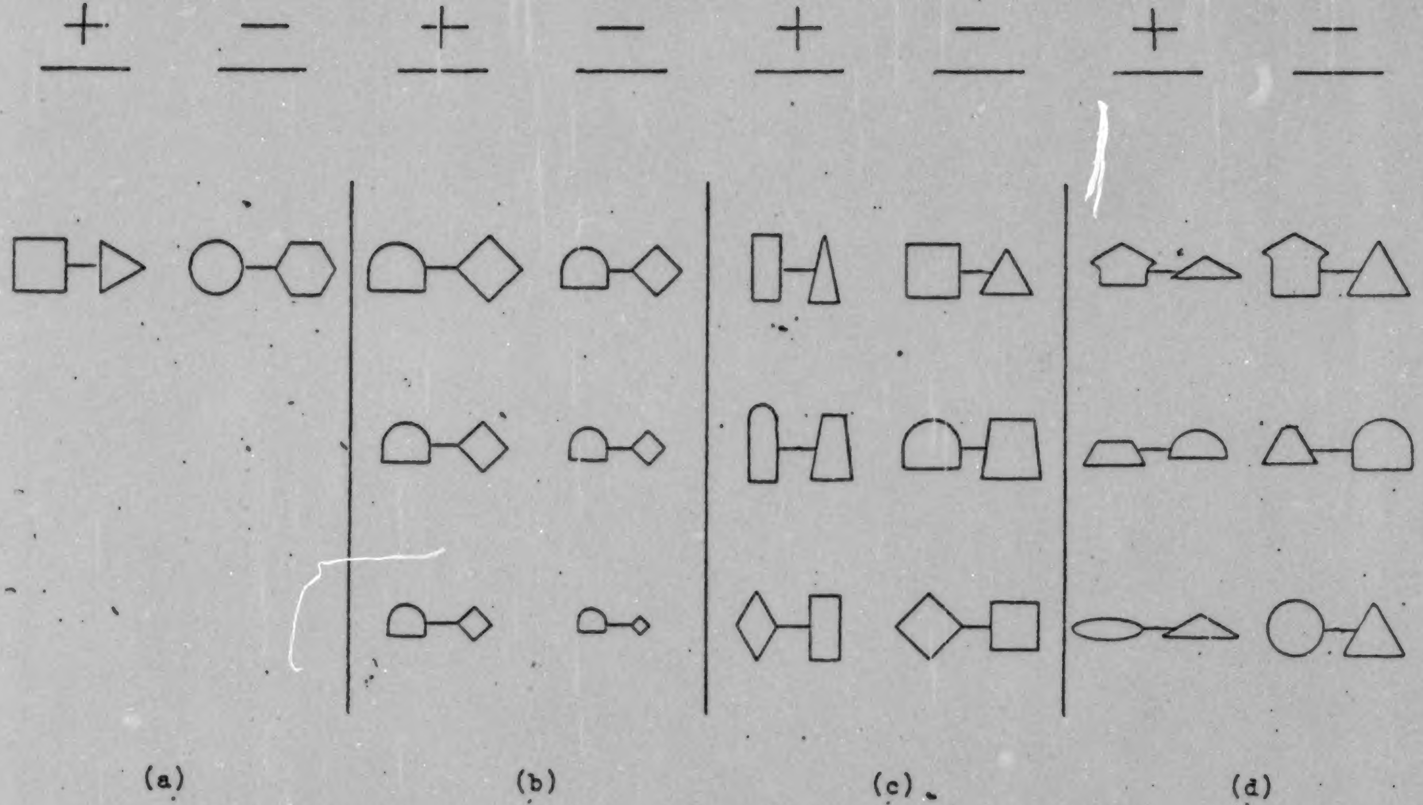


Figure 2. Examples of cues used for different types of problems: (a) cues for a discrimination problem, (b) cues for relational problem with larger shapes positive, (c) cues for relational problem with thinner shapes positive, and (d) cues for relational problem with flatter shapes positive.

sizes, the problem required a comparison of the two cues presented on each trial.

The second relational problem required the subject always to select the thinner of two pairs of similar shapes. From trial to trial four different pairs of positive and negative cues were rotated according to a random sequence. Thus the shape of the relevant cues was unpredictable.

In the third relational problem the subject had to select the flatter of two pairs of similar shapes. Again, since four sets of cues were used, the shape of the relevant cues was unpredictable.

The other general class of stimuli, those making up the visual noise, were used as overlays with the problems described above. Stimuli for the visual noise were constructed from another library, consisting of 12 geometric shapes. These shapes, also line drawings, were placed randomly within two square areas, so that when an overlay was used with the stimuli for one of the problems, the noise covered both the positive and negative cues (See Figure 3). There were 40 overlays, representing four examples of each of ten levels of visual noise. Level 1, representing the absence of visual noise, had no shapes in either square area. Levels 2 through 10 had 2, 4, 6, 8, 12, 16, 20, 24, and 32 shapes in each square area.

Both the stimuli for the three types of tasks and the stimuli for the visual noise were drawn on 5" by 8" sheets of colorless cellulose acetate plastic framed in cardboard for ease of handling. The positive and negative cues for each trial of a problem appeared on a single sheet of plastic. The visual noise figures were stored in a box with ten compartments, so that the experimenter could quickly select an example

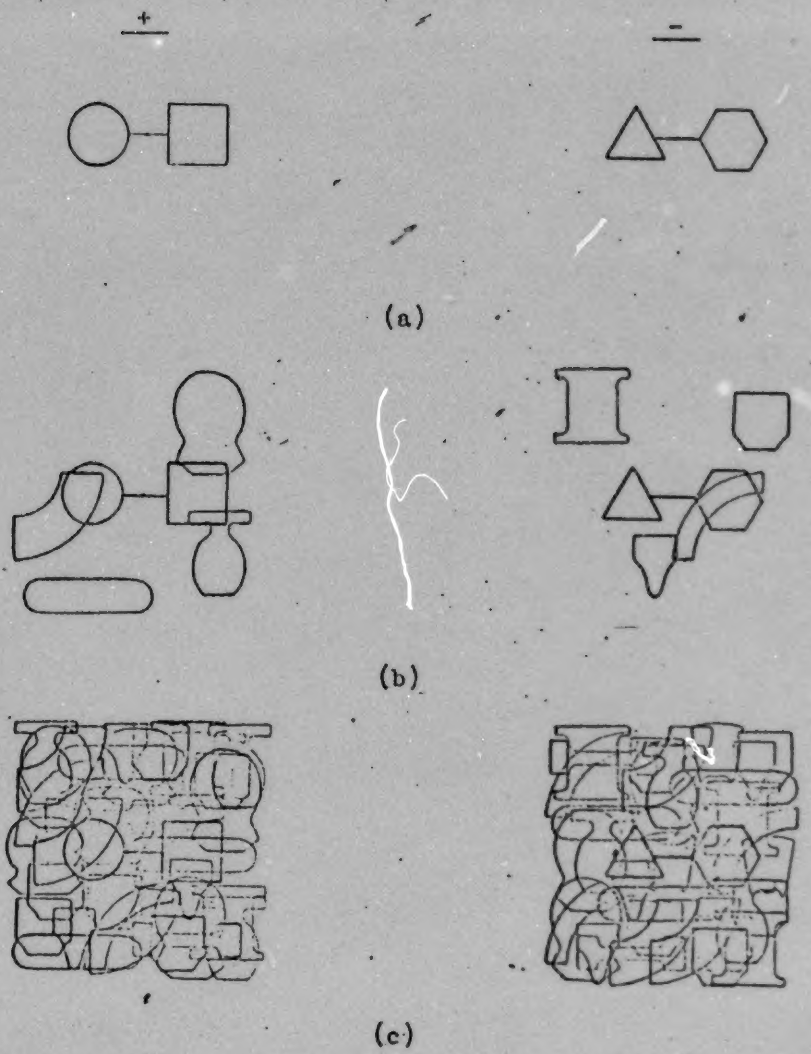


Figure 3. The cues for a discrimination problem with different levels of visual noise superimposed: (a) Level 1, or the absence of visual noise, (b) Level 3, and (c) Level 10.

of a particular level of visual noise.

With a Thermofax 66AG overhead projector, stimuli were projected onto a 5 ft. by 5 ft. movie screen. Subjects sat 4 feet from the screen. When the stimuli were projected onto the screen, the centers of the positive and negative cues were about three feet apart.

Procedure. Each subject was administered nine problems: three discriminations with constant position of cues, three discriminations with varying position, and three relational problems. Prior to these nine problems each subject received an unscored practice problem, a discrimination with constant position. Pilot testing had shown that kindergarteners improve their performance significantly between the first and second problems. The practice problem was an attempt to neutralize this learning or familiarization effect.

The stimuli for the first trial of the practice problem appeared on the screen. Using a pointer on the transparent plastic on which the stimuli were drawn, the experimenter said:

> Look at the shapes I am pointing to. In this game these are the shapes I am thinking of. Sometimes they will be on one side of the screen, and sometimes on the other side. When you find the shapes I am thinking of, point to the side of the screen where you see them.

The stimuli for the second trial then appeared, and the subject pointed to one side of the screen. If the subject did not seem to understand the procedure, the instructions were repeated. Only a few subjects had to have the instructions repeated more than once. The stimuli for successive trials were then presented until the subject reached a criterion of ten consecutive correct choices. At this point the experimenter began to superimpose overlays of visual noise on the stimuli of the discrimination.

Starting at Level 2, the level of visual noise was increased by one after each correct choice, until the subject made an error. Depending on the subject's choice, the experimenter said, "Good," or "Not that time." An error after the initial criterion, or a correct choice at Level 10 of visual noise terminated the practice problem. Immediately after the practice problem the nine scored problems were administered.

The procedure for the six discrimination problems was identical to the procedure for the practice problem, except that only four consecutive correct responses were required before the addition of noise.

The relational problems began with a different set of instructions:

> Look at the shapes I am point to. Notice that they look like the other shapes, except that they are bigger (thinner/flatter). Your job is always to find the shapes that are bigger (thinner/flatter). When you find them, point to the side of the screen where you see them. Sometimes they will be on one side of the screen, and sometimes they will be on the other side.

Otherwise the procedure was the same as for the discrimination problems.

Throughout the task the examples of visual noise were rotated within levels: the experimenter always drew an overlay from the left of the appropriate compartment and returned it to the right. The time to administer the task ranged from 30 to 40 minutes.

Since the experimental design demanded comparison of performance on the three types of problems, it was important to control for the order of their administration. This was especially true because in an earlier study (White and Mansfield, 1969) subjects had shown either improvement or decrement in performance over time. Therefore, the nine problems were always administered in three blocks, with each type of problem represented once in each block. With this constraint of blocking by type of problem, six different orders of presentation were selected. Thus in the same block different subjects received different problems. Each subject was randomly assigned one of the six orders.

To insure that any differences in performance on the three types of problems would not be due to differences in the particular stimuli used as cues, there were two alternate sets of stimuli. Half the subjects received one set, and half received the other. For the discrimination problems the two sets had the positive and negative cues interchanged. Pilot testing had indicated that with visual noise superimposed, most kindergarten and second grade subjects look only for the positive cue. The alternate sets had different shapes for the relational problem in which size was relevant. The reader will recall that in this problem the shape of the relevant cues did not change. But the alternate sets had the same stimuli for the other two relational problems, since in these problems the cues did change from trial to trial.

Auditory Task

The auditory task tested the subject's ability to detect a target message through different amounts of auditory noise. The task required the subject to point to one of eight familiar objects drawn on a laminated sheet of paper before him. The subject wore a set of headphones connected to two tape recorders and a stereo amplifier, so that a signal played on one tape recorder and noise played on the other were mixed by the amplifier and sent to both ears. While a voice constituting the signal told the subject successively to point to different objects, noise, at any of eight graded levels of intensity, could be superimposed. The subject first pointed to the objects correctly in the absence of noise. Then, after each correct response, the noise level for the next trial was increased by one, until the subject made an error. Next, the noise was set at such a high level that hearing the signal was impossible. And after each failure to point to the object indicated by the signal, the noise level was decreased by one, until the subject first pointed correctly. The procedure was repeated five times at each of three levels of signal volume, so that at each level five ascending and five descending estimates of the subject's threshold for noise were obtained.

Apparatus. Both the subject and the experimenter wore Realistic Model 33-195 headphones. The subject's headphones were connected to a Realistic Model SA100B stereo amplifier, which mixed the outputs from two Realistic Model 505 tape recorders. One of the tape recorders played the signal, and the other played the noise. Since the experimenter always had to hear the signal, his headphones were connected only to the output of the tape recorder playing the signal. Thus the experimenter never heard the noise.

Stimuli. The auditory task used two kinds of stimuli: the visual stimuli to which the subjects pointed, and the auditory stimuli making up signal and noise. The visual stimuli were colored line drawings of eight familiar objects: a bell, a boat, a sock, a clown, an apple, a wagon, a pencil, and a turtle. Since these objects appear very early in the Peabody Picture Vocabulary Test, in a section normally administered only to three-year-olds and retardates, it seemed reasonable to assume that the objects would be familiar to all kindergarten and second grade subjects in the present study. The eight objects, each drawn on a 1 3/4" by 1 3/4" square of paper, were mounted on an 8 1/2" by 11" piece of white paper, so that when this paper was placed horizontally in front of the subject, there were two rows of four objects. For protection of the stimuli, the paper was laminated with transparent plastic.

The auditory stimuli making up the signal consisted of the names of the eight familiar objects. Half of the names had two syllables; half had one syllable. Although the names were probably not equally discriminable from each other, there were no easily confusable pairs of names. A tape recording of a male voice successively told the subject to point to different objects: "Point to the apple, point to the clown, point to the boat..." Each object occurred equally often, and the same object never occurred twice in succession. The latter condition was necessary because pretesting had indicated that young children tend to keep their finger on one object until they hear the signal voice indicate another object. To insure a relatively uniform frequency of occurrence of each object throughout the signal tape, objects were selected for the tape in blocks of eight, with each object occurring once in each block. Within each block, however, the order of appearance of the eight objects was different. Every five seconds there was an instruction to point to a new object. And there were always at least three seconds between the end of one instruction and the beginning of the next. Pretesting had indicated that in the absence of noise most kindergarten children required less than one second to point to the correct object, if they had previously named each object and pointed to it three times. When noise was superimposed over the signal, choices often took longer, since lack of certainty forced the subject to decide between two or more alternatives. However, the interval between instructions could not be too long, or younger subjects were likely to lose interest in the task. In recording the tape, an attempt was made to maintain a constant level of loudness throughout the tape.

The noise stimuli to be superimposed over the signal were intended to maximally masking. To mask the signal consistently, the noise had to be continuous, without the pauses occurring throughout normal speech. Thus a mixture of several voices was necessary. But the quality of the noise had to be similar to that of the signal. A very large number of voices mixed together sounds like white noise, and therefore does not mask as effectively as a smaller number of voices. Experimentation suggested that the best mask of the signal was a small number of male voices mixed together. To make the noise tape, then, a male voice simultaneously recorded the same message on two tape recorders. The message was a passage from a textbook on child development, and contained none of the eight names used as auditory stimuli on the signal tape. The two tapes were then rewound and set to play back slightly out of synchronization. When the outputs of the two tape recorders were connected to the input of the stereo amplifier, the mixed output of the amplifier was recorded on a third tape recorder. After this process was repeated, there were two tapes, each with two voices mixed. These two tapes were then similarly mixed to make the actual noise tape, with four mixed voices. Each voice was the same male voice that had recorded the signal tape. Although it was possible to identify occasional words on the noise tape, it was impossible to follow any individual voice.

Since ascending and descending method of limits procedures were to be used to test a subject's ability to respond to a target message against different intensities of noise, it was necessary to define a number of levels of intensity of noise. Although the tape recorder playing the noise had a volume scale calibrated from 0 to 10, it was not clear that this was an interval scale; equal increments of volume at different points on the scale might result in unequal increases in perceived intensity. Furthermore, with the apparatus connected as in the present experiment, it was apparent that the characteristics of the volume scales on both tape recorders depended on the volume and balance settings for the stereo amplifier. For fixed settings of the stereo amplifier, the volume scale of the tape recorder playing noise was recalibrated into an interval scale with eight levels.

The rescaling required a separate experiment, that was administered to five adult subjects. At different settings of the volume control, these subjects listened to the noise tape, and, as the noise was turned down, judged when the perceived loudness was half the original level. From these judgments it was possible to mark off an equal interval scale for the volume control. The scaling experiment is described in detail in Appendix A.

Procedure. To familiarize subjects with the visual stimuli and their names, there was a pretraining period, occurring immediately before the actual auditory task. The experimenter pointed to and named each of the eight pictures. The subject was then asked to do the same thing. If the subject hesitated in naming any of the pictures, the experimenter supplied the name immediately. Afterwards, the experimenter pointed to any pictures the subject had not named and asked the subject to name them. All subjects, except three kindergarteners, were able to name all the pictures the first time through the series. No subject had to go through the series more than twice. Next, selecting pictures randomly, the experimenter instructed the subject: "Point to the apple. Point to the clown. Point to the boat..." This procedure continued until the subject had pointed to each picture three times.

Then the auditory task began. Explaining the apparatus and task, the experimenter said:

> Now we are going to play another pointing game. These are headphones. (The experimenter pointed to the two sets of headphones.) You will wear one set, and I will wear the other. This time the voice telling you what to point to will come from the tape recorder. (The experimenter pointed to one of the tape recorders.) Whenever you hear the voice, point to what it says. Sometimes it will be hard to hear what the voice says, because you will also hear some noise that sounds like a lot of men talking together. Sometimes the noise will be so loud that you cannot hear what the voice says to point to. But listen hard, because sometimes, even when the noise is loud, you will be able to hear what the voice says to point to.

The experimenter then put the subject's headphones in place, and put on his own headphones. With the "signal" and "noise" volume controls set at 2 and 0, respectively, both tape recorders were turned on. Thus the subject heard only the signal tape. After he had pointed correctly five times, noise was gradually added. Beginning at Level 1, the noise level was increased by one after each correct response, until the subject made an error. Subjects pointed correctly only at Levels 1 and 2. When the subject made an error, the level of noise present on the last trial before the error was recorded, and a descending series was then begun. Since pretesting had shown that adult subjects were unable to hear the signal with the noise at Level 3, the descending series was begun at Level 3 of noise. After each failure to point correctly, the level of noise was decreased by one, until the subject pointed correctly, and the level of noise present on that trial was recorded. The procedure was repeated until the subject had completed five ascending and five descending series.

Next the signal was set to 4 , for ten more alternating ascending and descending series. The procedure was similar to that for the first ten series, but with the signal volume set to 4 descending series began with the noise at Level 6 .

When the second ten series were completed, the signal was set to 6 , for the last ten series. Again, the method of limits procedure was the same, but the descending series began with noise at Level 8 .

Thus at each of three levels of signal volume there were five ascending and five descending estimates of a subject's ability to detect a target message through noise.

Results

The results for the visual task are presented first. The effects on performance of age level, sex, and type of problem are analyzed. Another analysis considers the effects of age level and sex on changes in performance over the three blocks of problems. Next, PPVT IQ scores are presented, and the performance of high- and low-IQ subjects on the visual task is analyzed. The results for the auditory task follow. Groups high and low in auditory performance are compared on the visual task. Finally, a correlational analysis is used as a different approach to the analysis of the relations between the variables of the study.

Visual Task

It will be recalled that subjects learned to respond correctly on each visual problem before noise was added. The noise level was then increased until the subject either made an error or chose correctly at Level 10 of noise. The highest noise level at which the subject responded correctly was taken as an estimate of the subject's capacity for noise. Thus there were nine estimates, corresponding to the nine problems. It will be remembered that the problems were of three types: simple discriminations, discriminations with varying position, and relational problems, also with varying position. For each type of problem there were three estimates of a subject's capacity for noise. The average of these estimates was a subject's score for that type of problem. Table 1 shows the scores for kindergarten and second grade boys

Table 1

Mean Scores on Visual Task: By Problems,

Grade Level, and Sex

Group	Type of problem		
	Discrim.; constant position	Discrim.; varying position	Relational; varying position
Kindergarten			
Boys	7.2	7.0	5.3
Girls	7.8	6.8	4.9
Second Grade			
Boys	9.3	9.3	7.6
Girls	9.3	9.0	7.0

and girls on the three types of problems.

A three-way analysis of variance was performed, with sex of subject and grade level as between-subjects effects, and type of problem as a within-subjects effect (Lindquist, 1953). The main effect of grade level was significant ($F = 41.5$; $p < .01$), as was the main effect of type of problem ($F = 32.8$; $p < .01$). Thus second graders performed better than kindergarteners, and the three types of problems did produce different levels of performance.

The order of difficulty of the three types of problems was examined by testing for differences between means for the three types of problems. The difference in performance on the two types of discrimination problems was not significant for second graders, but almost reached significance for kindergarteners ($t = 1.63$; $p = .07$, one-tailed). Thus varying the position of the cues in the noise fields had no effect on the performance of second graders, but tended to lower the performance of kindergarteners. For the two types of problems with varying position there was a marked difference in performance. The relational problems were more difficult, both for kindergarteners ($t = 6.34$; $p < .001$, two-tailed) and for second graders ($t = 4.83$; $p < .001$, two-tailed).

In the analysis of variance described above, sex of subject was not significant, and there were no significant interaction effects. An interaction had been predicted between the effects of grade level and type of problem. It was expected that kindergarteners would perform almost as well as second graders on the discrimination problems but much more poorly on the relational problems. Despite the failure to find a significant interaction between the effects of grade level and type of problem, the prediction was not necessarily disconfirmed. A problem in the scaling of the visual noise levels complicated the interpretation of the interaction. The scaling problem will be discussed later.

The next section of the analysis for the visual task considered changes in performance over time. Examination of individual protocols showed that performance improved over time for some subjects, but declined for others. Table 2 shows the mean scores for each of the three blocks of problems. Another three-way analysis of variance was performed, this time with sex of subject and grade level as between-subjects effects and blocks as a within-subjects effect (lindquist, 1953). The main effect of blocks was significant ($F = 6.46$; $p < .01$). A subsequent t-test showed that there was a significant difference in performance between Blocks I and II ($t = 7.70$; $p < .001$, 2-tailed). There was no significant difference in performance between Blocks II and III. Thus the effect of blocks was due primarily to improvement between the first and second blocks. The analysis of variance did not find significant interactions between the effect of blocks and the effects of either grade level or sex. Nor was the triple interaction between blocks, sex, and grade level significant. Thus the improvement between the first two blocks was unrelated to grade level or sex.

PPVT IQ and Performance on Visual Task

According to the test manual (Dunn, 1965) raw scores on the PPVT were transformed to IQ scores. Table 3 presents the means and standard deviations for these IQ scores. Boys had higher scores than girls, both at the kindergarten level ($t = 5.37$; $p < .001$) and at the second grade level

Table 2

Mean Scores on Visual Task: By Blocks,
Grade Level, and Sex

Group	Blocks		
	I	II	III
Kindergarten			
Boys	5.8	6.8	6.9
Girls	6.3	6.5	6.7
Second Grade			
Boys	8.2	9.1	8.8
Girls	8.1	8.6	8.5

Table 3

Means and Standard Deviations of PPVT IQ Scores

Group	N	Mean	S. D.
Kindergarten			
Boys	15	118.6	15.3
Girls	15	109.9	9.8
Second Grade			
Boys	15	111.3	13.9
Girls	15	107.4	17.4

($t = 2.53$; $p < .02$). This sex difference was not anticipated, and no explanation is offered for it.

To analyze the relationship between PPVT IQ and differential performance on the three types of problems of the visual task, the kindergarten set of IQ scores and the second grade set were each divided at their median, so that at each grade level there were equal high- and low-IQ subgroups. Table 4 shows the mean scores of these groups on the three types of visual problems. A three-way analysis of variance tested the effects of grade level, IQ, and type of problem on visual noise threshold. Grade level and IQ were treated as between-subjects effects, and type of problem as a within-subjects effect (lindquist, 1953). Previously, the effects of grade level and type of problem had been found to be significant. The present analysis of variance demonstrated a significant effect of IQ ($F = 6.61$; $p < .05$). Further analysis showed that this effect of IQ was significant at the kindergarten level ($F = 7.16$; $p < .05$), but not at the second grade level ($F = 1.60$; n.s.). Only at the kindergarten level did high-IQ subjects perform significantly better than low-IQ subjects. Inspection of Table 4 suggests why IQ was not related to visual performance among second graders. For each visual problem the highest possible score was 10. But on the two types of discrimination problems the average scores of both high- and low-IQ second graders were between 9 and 10. Since most second graders could cope with the highest levels of visual noise on the discrimination problems, there was little variability in performance, and the scores were unrelated to IQ.

The analysis of variance found no significant simple interaction effects. An interaction had been predicted between the effects of IQ

Table 4

Mean Scores on Visual Task: By Problems,

Grade Level, and IQ

Group	Type of problem		
	Discrim.; constant position	Discrim.; varying position	Relational; varying position
Kindergarten			
High IQ	8.2	7.7	5.4
Low IQ	6.8	6.2	4.8
Second Grade			
High IQ	9.3	9.3	8.0
Low IQ	9.3	9.0	6.7

and type of problem. Under this hypothesis the scores of high- and low-IQ subjects had been expected to differ more on the relational problems than on either of the two types of discrimination problems. It was assumed that the effect of IQ would be greater on the relational than on the discrimination problems. The failure to find the simple interaction between IQ and type of problem meant that the prediction did not hold for the subjects as a whole.

However, the analysis of variance did show a significant triple interaction between the effects of grade level, IQ, and type of problem ($F = 3.16$; $p < .05$). The meaning of the triple interaction was that the prediction outlined above held for second graders but not for kindergarteners. To analyze the triple interaction, first consider the scores for kindergarteners in Table 4. Notice the difference between the high- and low-IQ groups on each type of problem. For the simple discrimination problems this difference was 1.4, and for the discriminations with varying position it was 1.5. But for the relational problems the difference was only 0.6. Thus for kindergarteners IQ had a much greater effect on the discrimination problems than on the relational problems. Now consider the second grade scores. Again, observe the difference between the high- and low-IQ groups on each type of problem. There was no difference on the simple discriminations, and on the discriminations with varying position the difference was only 0.3. But on the relational problems the difference was 1.3. Thus for second graders IQ had a greater effect on the relational problems than on the discrimination problems.

Any conclusions about the triple interaction should be very tentative. High-IQ and low-IQ second graders did not differ on the discrimination problems. Both groups were able to cope with the highest levels of visual noise used on these problems. Two interpretations were possible. The first was that at this age level IQ was really unrelated to performance on the discrimination problems. A second possibility was that the relation of IQ to discrimination performance was obscured by the ceiling on possible scores for the discrimination problems. With additional, denser levels of visual noise high- and low-IQ second graders might have differed on the discrimination problems. The data provided no means of deciding between the alternate interpretations. Furthermore, the triple interaction was sensitive to the scaling problem mentioned earlier. At the kindergarten level the failure to find the interaction between the effects of IQ and type of problem on visual noise threshold could have been due to unevenness in the scale of noise levels. The scaling problem is discussed later.

The principal result of this analysis of variance, then, was that the high-IQ groups in both kindergarten and second grade performed better than the low-IQ groups on the visual task. While it had been predicted that the difference between the scores of the high- and low-IQ groups would be greater on the relational problems than on the discrimination problems, the prediction held only for second graders.

The next analysis tested whether changes over time in performance on the visual task were related to IQ. Table 5 shows the mean thresholds of the high- and low-IQ kindergartners and second graders for the three blocks of problems. In a three-way analysis of variance IQ and grade level were treated as between-subjects effects and blocks as a within-subjects effect (Lindquist, 1953). Neither the simple interaction between

Table 5

Mean Scores on Visual Task: By Blocks, Grade Level, and IQ

Group	Blocks		
	I	II	III
Kindergarten			
High IQ	6.7	7.3	7.3
Low IQ	5.5	6.1	6.2
Second Grade			
High IQ	8.4	9.2	8.8
Low IQ	7.[illegible]	8.5	8.5

blocks and IQ, nor the triple interaction between blocks, IQ, and grade level was significant. Thus changes in performance over time on the visual task were unrelated to IQ.

At this point a summary of the results for the visual task is appropriate. Visual noise thresholds differed significantly for the three types of problems. For kindergarteners, but not for second graders, the discriminations with varying position were more difficult than the discriminations without varying position. And at both grade levels the relational problems were more difficult than the discrimination problems. Throughout the visual task second graders performed at higher levels than kindergarteners. When subjects at each grade level were divided into high- and low-IQ subgroups, the high-IQ group at each grade level had higher thresholds for noise than did the low-IQ group. But among second graders the high-IQ group was superior to the low-IQ group only on the relational problems. Finally, there was a general tendency for improvement in performance between the first and second blocks of problems. This improvement occurred regardless of sex, grade level, or IQ.

Auditory Task

On the auditory task, it will be recalled, subjects were required to point to the pictures indicated by a male voice. This voice was masked by different intensities of noise. On ascending runs the voice was first presented without noise. The intensity of the noise was then raised in graduated increments, until the subject did not point correctly. On descending runs the voice was at first completely masked by the noise, the intensity of which was then decreased by graduated amounts, until the subject pointed correctly. For both ascending and descending runs a subject's score was the highest noise level at which he pointed correctly. Because of the different consequences of errors in the two types of runs, the scores derived from descending runs were generally higher than those derived from ascending runs. An error due to momentary inattention early in an ascending run terminated that run, even though the subject might have been able to respond correctly under much higher noise levels. If a subject made an error early in a descending run, he always had another chance to respond at the next lowest noise level.

For each level of signal volume a subject's average score was computed. Scores from ascending and descending runs were pooled. Table 6 presents the mean scores for kindergarten and second grade boys and girls. Clearly, the higher the signal volume, the more noise was needed to mask the signal. But the different levels of signal volume did not constitute conceptually different conditions. It seemed reasonable to assume that the same ability to detect a signal message through noise was being measured at each level of signal volume. Therefore, the three scores for each subject were combined. For each level of signal volume the scores of the sixty subjects were placed in one distribution. With this distribution as a base, the scores were transformed to T scores. Thus each subject had three T scores, representing performance at each level of signal volume, and the mean of these T scores was an index of his overall performance on the auditory task.

Table 7 presents the overall scores for kindergarten and second grade boys and girls. A high score indicated superior ability to detect a signal through noise. As expected, second graders were superior t

Table 6

Mean Thresholds on Auditory Task

Group	Level of signal volume		
	2	4	6
Kindergarten			
Boys	0.6	2.2	3.4
Girls	0.5	1.7	3.0
Second Grade			
Boys	0.9	2.7	3.7
Girls	0.8	2.7	3.9

Table 7

Means of Overall Auditory Scores

Grade level	Boys	N	Girls	N
Kindergarten	48.1	15	42.7	15
Second grade	54.5	15	54.8	15

kindergarteners ($t = 34.3$; $p < .001$). Boys were superior to girls at the kindergarten level ($t = 7.1$; $p < .001$), but not at the second grade level ($t = 1.2$; n.s.). The sex difference in kindergarteners, it will be remembered, was associated with an IQ difference favoring the boys. The low correlation between IQ and overall auditory score ($r = .18$; n.s.) could not explain the sex difference, for the correlation between sex and overall auditory score was much higher ($r = .36$; n.s.). The sex difference in the auditory performance of kindergarteners was not anticipated, and no explanation is offered for it.

The next section of the analysis of results investigated a possible relationship between performance on the auditory and visual tasks. The asumption was that some central process might facilitate both auditory and visual selective attention. At each grade level groups high and low in auditory ability were created by dividing the overall auditory scores at the median. Table 8 shows the performance of these high and low auditory groups on the visual task. An analysis of variance tested the effects of auditory ability, grade level, and type of visual problem on visual noise threshold. Auditory ability and grade level were between-subjects effects, while type of visual problem was a within-subjects effect (Lindquist, 1953). The main effect of auditory ability was not significant. However, the interaction between auditory ability and grade level was significant ($F = 5.04$; $p < .025$). The interaction was primarily due to the significant simple effect of auditory ability at the kindergarten level ($F = 5.17$; $p < .05$). Auditory and visual performance were positively related only at the kindergarten level. It will be recalled that at the second grade level visual performance was close to a ceiling.

Table 8

Mean Scores on Visual Task: By Problems,

Grade Level, and Auditory Performance

Group	Type of problem		
	Discrim.; constant position	Discrim.; varying position	Relational; varying position
Kindergarten			
High aud.	8.2	7.3	5.4
Low aud.	6.7	6.5	4.8
Second Grade			
High aud.	9.2	8.9	7.1
Low aud.	9.4	9.4	7.6

Thus visual performance was unlikely to be positively related to performance on any other task.

Correlational Analysis

As another approach to the inter-relationships among the variables of the study, a correlational analysis was performed. Pearson product-moment correlations were computed for the following variables: mean performance on the three blocks of the visual task, PPVT IQ, overall auditory score, and sex of subject. The results for the kindergarteners appear in Table 9, and those for second graders in Table 10.

The contrast between correlations for kindergarteners and correlations for second graders is enlightening. For kindergarteners, but not for second graders, the three visual problems were inter-correlated significantly. While for kindergarteners IQ was correlated positively, although not significantly, with all three types of visual problems, for second graders IQ was positively correlated only with the relational problems. These results were consistent with the earlier observation that second graders reached a ceiling of performance on the two types of discrimination problems.

The correlation between IQ and visual performance increased on successive blocks for kindergarteners, but decreased on successive blocks for second graders. Apparently, as the kindergarteners became more familiar with the visual task, they reached a level of performance commensurate with their ability. In second graders, however, familiarization with the visual task pushed performance closer to the ceiling on each successive block, so that the relation of visual scores to IQ declined over time.

Table 9

Correlations Among Variables for Kindergarten Subjects

Variable	Variable no. 1	2	3	4	5	6	7	8	9
1. Discrim.; constant position		.52**	.54**	.67**	.72**	.62**	.26	.22	.16
2. Discrim.; var. position			.60**	.70**	.73**	.61**	.36	.12	-.06
3. Relational; var. position				.66**	.79**	.62**	.18	-.11	-.12
4. Block I mean					.62**	.34	.16	-.16	.12
5. Block II mean						.52**	.25	.02	-.07
6. Block III mean							.37*	.40*	-.07
7. PPVT IQ								.18	-.33
8. Overall aud. score									-.36
9. Sex (M=1/F=2)									

$^{*}p < .05$
$^{**}p < .01$

Table 10

Correlations Among Variables for Second Grade Subjects

Variable	Variable no.								
	1	2	3	4	5	6	7	8	9
1. Discrim.; constant position		.24	-.02	.25	.16	.39*	-.01	-.15	.03
2. Discrim.; var. position			.23	.37*	.41*	.51**	.18	.44*	-.16
3. Relational; var. position				.65**	.62**	.70**	.50**	-.15	-.14
4. Block I mean					.11	.42*	.46*	-.16	-.01
5. Block II mean						.51**	.30	-.42*	-.22
6. Block III mean							.23	-.16	-.14
7. PPVT IQ								.13	-.13
8. Overall aud. score									.03
9. Sex (M=1/F=2)									

*$p < .05$
**$p < .01$

The correlations between IQ and the three types of visual problems supported the results of earlier analyses. For kindergarteners these correlations were positive but low, suggesting that visual performance was partly independent of IQ. For second graders, on the other hand, there appeared to be no correlation between IQ and either type of discrimination problem. Once again, the probably cause was that second graders performed so close to a ceiling on the discrimination problems that their scores were meaningless. Only performance on the relational problems was positively related to IQ. Of the three types of visual problems, the relational ones correlated most highly with IQ in second graders, but least highly with IQ in kindergarteners. This finding was consistent with the triple interaction found earlier, between the effects of IQ, grade level, and type of visual problem. At the kindergarten level the correlation between IQ and performance on the relational problems ($r = .18$; n.s.) was unexpectedly low, especially when compared with the same correlation at the second grade level ($r = .50$; $p < .01$). But the low correlation for kindergarteners may have been another result of the problem in the scaling of the visual noise levels.

The correlations of auditory performance with visual performance were generally low and inconsistent. Consider first the correlations for kindergarteners. Correlations of the auditory measure with the two types of discrimination problems were positive but low, and not significant. However, these correlations must have been responsible for the simple effect of auditory ability on visual noise threshold found earlier. For performance on the auditory task was not positively correlated with performance on the relational problems.

Now consider the correlations for second graders. The correlations of the auditory measure with the two types of discrimination problems were negative. However, these correlations were probably meaningless, since the second graders scored close to the ceiling on both types of discrimination problems. The correlation of the auditory measure with the relational problems was also negative (r = -.15; n.s.), but too low to require explanation. Thus there was no evidence that visual and auditory performance were positively related at the second grade level.

The correlations between the auditory measure and IQ were low but positive, both for kindergarteners (r = .18; n.s.) and for second graders (r = .13; n.s.). Thus there was some slight evidence that IQ affected performance on the auditory task.

The correlations of sex with other variables were consistent with the sex differences reported earlier. In kindergarteners sex was unrelated to performance on the three types of visual problems. The correlation of sex with IQ (r = -.33; n.s.) was consistent with the superiority of the boys reported earlier. And the correlation of sex with auditory performance (r = -.36; n.s.) was consistent with the boys' superiority reported earlier for the auditory task. At the second grade level the correlational analysis demonstrated that sex was unrelated to visual performance, auditory performance, and IQ.

In summary, the correlational analysis corroborated the results of the earlier analyses. There was some evidence that IQ was positively related to visual performance at both grade levels. In kindergarteners

IQ was correlated more highly with the discrimination problems than with the relational problems. In second graders, however, IQ was positively correlated only with performance on the relational problems. Auditory performance was positively correlated with visual performance only at the kindergarten level and only for the discrimination problems. And the correlations between IQ and auditory performance were positive but low at both age levels.

Discussion

Visual Task

The results suggested an improvement with age in the ability to cope with visual noise. Second graders were consistently able to cope with higher levels of noise than kindergarteners. Furthermore, the disruptive effect of noise depended on the difficulty of the underlying problem. At both grade levels performance on the relational problems was more easily disrupted by noise than performance on the discriminations. The greater difficulty of the relational problems was probably due to the need to locate and compare both relevant cues. In the discriminations, varying the position of presentation of the relevant cues resulted in slightly lowered scores for kindergarteners, but had no effect on second graders' scores. The varying position condition undoubtedly lengthened search time at both grade levels. And with longer search time, kindergarteners may have been more likely to forget the relevant cues.

There was also evidence that the ability to cope with visual noise was related to IQ, as tested by the PPVT. Among the kindergarteners high-IQ subjects coped with higher noise levels than low-IQ subjects on all three types of visual problems. An unexpected result was that the superiority of the high-IQ subjects was more apparent on the discriminations than on the relational problems. Among second graders the high-IQ subjects were superior to the low-IQ subjects only on the relational problems. However, since the second graders attained maximal scores on the discrimination problems, these scores were not likely to be related to IQ.

Because of certain technical problems to be discussed later, all these results must be accepted somewhat tentatively. A problem in the scaling of the visual noise levels complicated the interpretation of differential performance by different groups on the three types of visual problems.

While the study suggested that the ability to cope with visual noise in problem solving was related to age and IQ, no attempt was made to determine what processes were involved in the ability. However, some speculation is possible. First, the noise may have interfered with the memory for the relevant shapes. Observation suggested that the interference was greater on the discriminations than on the relational problems. On the relational problems, all that had to be remembered from trial to trial was a verbal concept: "larger," "thinner," or "flatter." It was probably easier to remember a verbal concept than a particular pair of shapes. While kindergarteners often reported forgetting the target shapes, such lapses of memory were much rarer in second graders.

Another process involved in coping with visual noise was systematic scanning. It was the experimenter's impression that this ability was much more apparent in second graders than in kindergarteners. The experimenter observed that second graders would exhaustively scan one noise field before turning to the other field. In contrast, kindergarteners would often shift attention between the two fields several times before making a response. Failure to scan the noise fields systematically and exhaustively inevitably increased search time and thus made it more likely that the relevant cues would be forgotten.

Coping with visual noise also required the inhibition of impulsive responding. In the discrimination problems subjects sometimes made incorrect choices on the basis of noise configurations similar to one of the positive shapes. In the relational problems, too, subjects would sometimes impulsively respond to a large, thin, or flat noise figure. Impulsive responding was most common in the relational problem with size relevant. To be consistently correct, a subject had to locate both relevant cues and compare them. Failure was common when both the positive and negative shapes for a trial were relatively large. If the subject found the negative shapes first, he was likely to point to them immediately, instead of first finding the relevant shapes in the other noise field and making a comparison.

Thus observation suggested that three factors: memory for shapes, systematic scanning, and inhibition of impulsive responding, were involved in the ability to cope with noise on the visual task. Although the study gave no indication as to which of these factors was most important in determining performance, there is evidence elsewhere that all three factors are associated with developmental change.

Vernon's (1960) observations on young children's perception of complex forms support the notion of development in the ability to remember shapes. She noticed (p. 12) that when children were presented with relatively simple forms, they were likely to see the forms as wholes, and to neglect details. An attentional limitation of this type would certainly be likely to result in poor memory for shapes. The attentional limitation was much less likely to be found in older children.

There is also evidence that the tendency to scan systematically develops with age. Teegarden (1933) required children to name pictures of familiar objects arranged in an array of five rows and five columns. While older children tended to name the objects systematically, row by row or column by column, younger children were more likely to adopt an irregular, unsystematic order. If, in the present study, the kindergarteners' scanning of the noise fields was also unsystematic, then their tendency to shift attention between the noise fields several times before making a response is understandable. With an unsystematic search strategy, they would have no way of knowing whether they had exhausitvely scanned a noise field. After looking at one noise field for awhile, they would have no reason not to switch to the other field. They might switch noise fields several times before they either found the positive cue or gave up and made a guess.

Impulsivity, the third factor affecting performance on the visual task, may also change developmentally. The greater impulsivity of younger than older children is a commonplace observation of classroom teachers. However, experimental research has more often treated impulsivity as a personality trait or dimension of cognitive style than as a characteristic of behavior that changes with age (Kagan, Rosman, Day, Albert and Phillips, 1964). Nevertheless, in one study (Kagan, Rosman, Day, Albert, and Phillips, 1964) impulsivity, as measured by response latency on a task requiring subjects to find hidden figures, was found to be negatively associated with the tendency to form analytical concepts. And the tendency to form analytical concepts was found to be related positively to age. This indirect, correlational evidence is not conclusive, but it does suggest that impulsivity tends to decline with age.

Auditory Task

The auditory task strongly suggested a development with age in the ability to cope with noise. In identifying target words, second graders could cope with much higher intensities of noise than could kindergarteners. The research suggested a weak positive relationship between IQ and auditory performance. But the correlations between these measures were very low and not significant. At the kindergarten level subjects with high auditory performance scored higher on the visual task than subjects whose auditory performance was relatively low. But the correlation between auditory and visual performance was low. At the second grade level there was no evidence of a relationship between auditory and visual performance.

Observation suggested that at least three abilities were required by the auditory task. One important requirement was that the subject be able to attend consistently when the target words were presented. Although the auditory task took only 25 minutes to administer, it was relatively tedious. And distractions from outside the experimental situation were abundant. In contrast to the visual task, which allowed the subject a period of time to direct attention to the relevant cues, the auditory task demanded attention to the relevant cues at the time they were presented. Some subjects frequently seemed to be 'tuned out' when target words were being presented. Moments of inattention became more frequent as the task progressed. The capacity to maintain set consistently over time was probably a function of attention span. But if attention span was an important determinant of performance on the auditory task, the superiority of the boys over the girls at the kindergarten level is puzzling. Boys in this age range are usually thought to have shorter attention spans than girls. Possibly the greater eagerness of the boys to please a male experimenter offset their normally shorter attention spans.

A second ability required by the auditory task was to be able to determine when the target words were being presented. When there was moderate noise, some subjects, even when they appeared to be attending, often appeared not to realize that a target word had been presented. Such subjects were poor at differentiating signal from noise.

The auditory task also required the ability to make use of the set of response alternatives. Often noise degraded perception of the target words, so that only crude features, such as the number of syllables, a vowel sound, or a consonant sound, were available as cues for identification. On the basis of such features all but one or two of the response alternatives could often be eliminated. But some subjects were unable to use the information provided by the set of alternatives. For example, one such subject thought he had heard the word, "frog," and declared that there was no frog among the alternatives. The word, "frog," has the same number of syllables, and the same vowel sound as the actual target word, "sock." If the subject had considered the response alternatives, he might have guessed correctly.

Using the set of response alternatives presupposed both familiarity with the alternatives and the ability to listen for critical features distinguishing the alternatives. Despite the pretraining period, it cannot be assumed that all subjects were equally familiar with the alternatives. Rate of familiarization was probably a function of age and intelligence. The tendency to listen for critical features distinguishing the alternatives was also probably associated with age and intelligence. By varying the length of the familiarization period and the size of the set of response alternatives, these relationships could be tested.

Because of the differences between the auditory and visual tasks, the tasks demanded somewhat different abilities. It was suggested that on the visual task memory for shapes may have been an important determinant of performance. On the auditory task it was not essential that anything be remembered from trial to trial. However, when the perceived fragments of a masked stimulus word did not permit immediate identification of the word, it was presumably necessary to remember these fragments while comparing them with the set of response alternatives. Thus the auditory task did require memory for incompletely perceived stimulus words during individual trials. Furthermore, it was stated earlier that to make use of the information provided by the set of response alternatives, a subject had to be familiar with the alternatives. Memory may also have affected the rate of familiarization with the alternatives. But in both cases, whatever memory was involved in the auditory task was verbal memory. The visual task required visual memory.

While the ability to scan systematically seemed to facilitate performance on the visual task, this ability was not required on the auditory task, since there was no need to determine the spatial location of the target stimuli.

Impulsive responding, which seemed to lower performance levels on the visual task, was not easy to observe in the auditory task. From a logical standpoint, if a subject was to make use of the set of response alternatives, by comparing them with an incompletely perceived stimulus word, he would have to inhibit impulsive responding. Inhibition should lead to consistently longer response latencies. However, since only three seconds were allowed for a response, it was difficult to observe differences between subjects in response latency. Such differences may have existed, and would have been apparent if response latency had been measured.

One ability that seemed important in the auditory task, the ability to sustain attention, may also have been important in the visual task. The visual task was tedious, and most subjects showed restlessness as the task progressed. Clearly, some kind of sustained attention was demanded. But on the visual task, in contrast to the auditory task, subjects had a period of time to mobilize their attentional resources on each trial. The need to mobilize attention on each trial was manifested by a cyclical pattern of inhibition of bodily movement during trials, and motor discharge between trials. The motor discharge after each trial seemed to indicate that attentional state required during the trials was tiring or stressful. Despite an increase in restlessness over time, the mobilization of attention appeared to be successful, since the performance of most subjects did not decline during the task. It will be recalled that at both grade levels average performance improved between the first two blocks and then remained constant from the second to the third block. Unlike the visual task, the auditory task did not allow time for attention to be mobilized; if a subject was not attending at the time a stimulus word was presented, he was likely to make an error. Thus the demand for sustained attention was more rigorous in the auditory task than in the visual task.

The different abilities required by the visual and auditory tasks have been discussed, and it seems appropriate now to consider some technical problems in both tasks. After these technical problems are discussed, a revised methodology, suitable for future studies, is outlined. Finally, some directions for future research are suggested.

Technical Problems in the Visual Task

In the analysis of the results for the visual task a scaling problem became apparent. The scaling problem is relevant to the failure to find two predicted interactions: the first between the effects of grade level and type of problem, and second between the effects of IQ and type of problem. The reader will recall that the index of performance for all visual problems was the highest level of noise at which the subject responded correctly. But with regard to their potential effect on problem difficulty, the noise levels formed an ordinal, not an interval scale. Clearly, each successive noise level increased problem difficulty. But the amount of increase was not necessarily constant from level to level. Increasing the noise level from five to six may have had a much greater effect on problem difficulty than increasing the noise level from seven to eight. Thus the relevance of the scaling problem to interaction effects is apparent. For example, Table I shows that the difference between performance on the discrimination problems with varying position and the relational problems was about the same for kindergarten as for second grade subjects. However, since the difference was measured at different segments of the noise scale for the two age groups, it was impossible to conclude that the differential effect of noise on the two types of problems was the same for both age groups. Indeed, it would have been just as fallacious to conclude that the interaction did not exist as to conclude that it did exist.

The same argument also applies to the existence of an interaction between the effects of IQ and type of problem. The predicted relationship between these effects was found only at the second grade level. And the opposite relationship was found at the kindergarten level, with the result that there was a significant triple interaction between the effects of grade level, IQ, and type of problem. But the scaling problem made it impossible to interpret these results with confidence, for the difference in performance between the high- and low-IQ groups was measured at different segments of the noise scale for each type of problem.

If cross-over interactions had been found, scaling would not have posed a problem. For example, if the kindergarteners had scored higher then the second graders on the discriminations but lower than the second graders on the relational problems, the existence of an interaction would have been clear, despite the scaling problem.

Future studies using the method of limits procedure to measure the effects of noise will have to deal with the scaling problem. One possibility is to scale the noise in a separate experiment. Using a matching-to-sample procedure, with a fixed time interval allowed for responses, the proportion of correct responses under different amounts of noise could be determined. On the basis of the results, new noise stimuli could be constructed, with the different levels forming an interval scale.

In the course of the study two other problems with the visual task became apparent. One problem was the exclusive use of errors in estimating the effects of noise. The use of this measure meant that each ascending series of trials produced only one index of capacity for noise. By also measuring response latency, some independent information could be gained from each trial. Response latency is probably more sensitive than error rate to the effects of noise.

A final problem was the use of familiar forms as target shapes. On the discrimination problems the subject had to remember the target shapes from trial to trial. Since some of the target shapes, particularly squares and circles, were more familiar than others, these shapes were presumably easier to remember. To eliminate extraneous variation due to differential familiarity of the target shapes, future studies might use unfamiliar, randomly generated polygons (Attneave and Arnoult, 1956) as target shapes.

Technical Problems in the Auditory Task

In the auditory task, as in the visual task, there were several unexpected sources of variation in performance. One source of extraneous variation was a differential susceptibility among the target words to masking by the noise. For any given level of signal there were some noise levels high enough to mask the signal completely and other noise levels low enough so that perception of the signal was virtually certain.

But there was a range of intermediate noise levels at which the stimulus words were heard only part of the time. It was the experimenter's clear impression that some words, such as "boat," "apple," and "wagon," were much more likely to be recognized at intermediate noise levels than were other words, such as "pencil," and "turtle." A possible explanation is that the vowel sounds the more easily recognized words are more distinctive against noise than are the vowel sounds of less easily recognized words. But consonant sounds also affected recognition at intermediate noise levels; the two words with the same initial consonant, "boat" and "bell," were frequently confused. Also, words were likely to be confused with other words having the same number of syllables. Intermediate noise levels degraded perception of the stimulus words, so that only crude features such as distinctive vowel sounds, initial consonant sounds, or the number of syllables, could be used to identify the words.

Since the stimulus words for individual trials were not recorded, it was impossible to perform statistical analyses of the frequency of identification of particular stimulus words at different noise levels. However, the differential vulnerability of the stimulus words to masking was a source of extraneous variation to which the method of limits procedure was particularly susceptible. Easily masked words occurring early in ascending runs often resulted in artificially low estimates of the amount of noise necessary to mask the signal. Similarly, very distinctive words occurring early in descending runs often resulted in artificially high estimates of the noise required for masking. Ideally, the method of limits procedure would require a set of stimulus words equally distinctive against noise. But there would probably be differences in distinctiveness in any set of stimulus words. It might therefore be easier to abandon the method of limits procedure and test each stimulus word a fixed number of times against several moderate noise levels. This procedure would provide independent information on each trial, while also controlling for differential susceptibility of the stimulus words to masking.

Another source of variation in individual performance was the inability of most subjects to sustain attention to the signal tape. It was mentioned earlier that the auditory task, unlike the visual task, required attention to the relevant cues at the time they were presented. With the method of limits procedure, lapses of attention were often critical; an error early in an ascending series determined the score for the series. Most subjects were unable to sustain attention throughout the task and therefore occasionally made critical errors early in ascending series. As a result, within individuals there tended to be rather high variability among the different estimates of capacity for noise. One way, to deal with this difficulty would be to allow the subject to control the time of presentation of the stimuli by pressing a button to indicate readiness. With subjects setting the pace of the auditory task, the task would measure the ability to differentiate signal from noise under optimal conditions. But it is possible that under optimal conditions subjects do not differ very much in their ability to attend selectively. It may be that the pressure of an externally determined pace makes selective attending difficult. When selective attending is required in everyday life, one cannot control the pace at which information is presented.

An alternative to allowing subjects to control the time of presentation of stimuli would be to eliminate the method of limits procedure. If, as was suggested before, each stimulus word were tested a fixed number of times against several levels of moderate noise, the effect of errors due to momentary inattention would be limited to individual trials. There would still be variability among each individual's estimates of noise capacity, but there would be many more estimates.

A Revised Methodology

If the study were to be repeated, certain changes would have to be made, to deal with the technical problems in the methodology of both the auditory and visual tasks. In the discussion of the technical problems these changes were suggested. The changes are summarized below:

Three methodological changes are suggested for the visual task. The most important one would be to use scaled noise levels, so that interactions between the effects of problem difficulty and other variables could be meaningfully interpreted. A second change would be to use unfamiliar shapes for the relevant cues. In the discrimination problems, then, the task of remembering the relevant cues would be equally difficult for all problems. Finally, the measurement of response latency would provide another, more sensitive indicator of the effect of noise. Response latencies would also constitute independent information on each trial. With these changes the visual task could be administered as in the present study.

For the auditory task the most important change would be to replace the method of limits procedure with a procedure testing the perception of each stimulus word against several noise levels of moderate intensity. The measure of capacity for noise would be the number of stimulus words identified at each level of noise. One advantage of the new technique would be that each trial would provide independent information. There would be no wasted trials at noise levels so low that identification of the target words would be virtually certain or so high that identification would be impossible. Momentary inattention would affect scores for individual trials, not scores for entire ascending runs. Furthermore, since each target word would appear an equal number of times at each noise level, extraneous effects due to differential susceptibility of the target words to masking would be controlled. Thus the new procedure would eliminate the technical problems of the present study.

A second suggested change in the auditory task would be to measure response latencies, so that the possible effect of impulsive responding could be studied. With these two changes the auditory task could be administered as in the present study.

Suggestions for Future Research

Future research on the development of the ability to cope with noise might proceed in several directions. The relationship between intelligence and selective attention merits further study. The PPVT was selected for its ease of administration and its relatively high reliability in the age range tested. In kindergarten children a moderate positive correlation was found between PPVT IQ and performance on the visual task. And it is possible that the correlation of the auditory task and IQ would be higher if the auditory task were modified, as suggested earlier, to cope with intra-individual variability in performance. But the PPVT, a vocabulary test, bears a very indirect relation to problem-solving ability. An intelligence test measuring problem-solving ability more directly would probably correlate more highly with the visual and auditory tasks. For, as was proposed earlier, problem-solving often entails coping with noise. Problem solving, it was earlier suggested, often requires separating relevant from irrelevant information, and hence, in a broad sense, the ability to cope with noise.

Several other findings suggest a relationship between IQ and the ability to cope with noise. Bar-Yam (1969, pp. 7-10) reviewed a number of studies evaluating the effects of directive and non-directive teaching on children of different ability levels. Directive teaching was traditional,"teacher-centered," and highly structured, while non-directive teaching was "learner-centered" and less structured. Bar-Yam concluded that lower-ability students tend to perform better under directive teaching, while higher-ability students tend to perform better under non-directive teaching, particularly in tasks requiring problem-solving. It could be argued that directive teaching includes less "noise" than non-directive teaching. In this case the poor performance of low-ability children under non-directive teaching may reflect their poorly developed ability to cope with noise.

Bissell (1970, p. 28) evaluating the effectiveness of structured and unstructured preschool programs for disadvantaged children, formed a conclusion parallel to Bar-Yam's. Bissell concluded that directive, highly structured programs tended to be more effective with the more disadvantaged of lower-class children, while non-directive, less structured programs tended to be more effective with the less disadvantaged of lower-class children. Presumably, the more disadvantaged children tested lower on intelligence tests than the less disadvantaged children. And again, the lower-ability, more disadvantaged children may have been less able than higher-ability children to cope with the greater amount of 'noise' in unstructured programs.

There is also a need for further developmental studies comparing selective attention in different sensory modalities. Although the present study found relatively low correlations between performance on the visual and auditory tasks, modifying the auditory task along the lines proposed earlier should increase these correlations. Performance on the visual and auditory tasks could also be compared with performance on a tactual task requiring selective attention. Gallin's (1960, 1961) tactual tasks, described earlier, might be adapted for this purpose.

A third area for future research is the investigation of the processes underlying the ability to cope with noise. On the visual task studies of eye movement might demonstrate the importance of systematic scanning strategies. In the discriminations the importance of memory for the target shapes could be studied in several ways. For example, the number of discrimination trials prior to the addition of noise might be systematically varied. More such trials should lead to better memory for the target shapes. The type of familiarization with the target shapes could also be varied. Before each problem some subjects could be required to trace copies of the target shapes. The measurement of response latencies might clarify the role of impulsive responding on both the visual and auditory tasks.

On the auditory task the importance of the ability to make use of the set of response alternatives could easily be tested by comparing performance in conditions using different numbers of response alternatives.

A final area for future research is the study of the psychophysiological concomitants of selective attention. Both in the present study and in an earlier study (White and Mansfield, 1969) focused attention during the visual task seemed to be associated with inhibition of bodily movement and an increase in general muscular tension. Between trials there was an increase of bodily movement and a relaxing of the muscles. It is likely that the cyclical pattern of motor restraint and motor discharge is reflected in a cyclical pattern of psychophysiological changes. There is some evidence that in adults a special psychophysical state is maintained during problem solving (Germana, 1968; Elias and White, 1969; Elias, 1970). The ability to adopt this psychophysiological mode probably develops with age. Younger children may be incapable of achieving an optimal mode. Or, if they can achieve an optimal mode, they may be unable to maintain it over a period of time. The analysis of psychophysiolcgical measures during tasks requiring selective attention might illuminate the development of changes in attentional capacity.

Appendix A

Rescaling the Volume Dial of the Tape Recorder Playing Noise to Create an Interval Scale of Perceived Loudness.

Method

Although the tape recorder playing the noise in the auditory task had a colume scale calibrated from 0 to 10, it was not clear that the scale was an interval one; equal increments of volume at different points on the scale might result in unequal increases in perceived loudness. The rescaling required a separate experiment, that was administered to five adult subjects. At different settings of the volume dial, the subjects listened to the noise tape, and, as the noise was turned down graduall , judged when the perceived loudness was half the original level. From these judgments, it was possible to mark off an equal interval scale on the volume dial.

Subjects

The subjects were five adult graduate students in psychology: two males and three females. The small number of subjects, necessitated by severe time pressure to develop and administer the auditory task before the subjects left school for vacation in June, did not appear to be a severe limitation, since for the purposes of the study only a crude approximation to an interval scale was necessary. Furthermore, consistency of judgments among the five subjects suggested that increasing the number of subjects would not substantially alter the derived interval scale. The experiment did assume that the adults' perceived loudness at different levels would be comparable to that of the children in the present study. Because the procedure of obtaining loudness judgements was tedious and at times stressful, it would probably have been very difficult to administer to children. And there was no obvious reason to expect that the results for children would differ from those obtained for adults.

Apparatus

The apparatus was the same as was used in the auditory task. As in the administration of the auditory task, the tape recorders playing signal and noise were connected to the stereo amplifier, the output of which fed into the subject's headphones. Both tape recorders were turned on, but the volume control of the tape recorder playing the signal was always set to zero, so that the subject heard only the noise. The volume and balance controls on the stereo amplifier were kept at the same fixed positions as in the auditory task.

Stimuli

The stimulus was the noise tape, played at different levels of loudness, in terms of the volume dial settings of the tape recorder. It will be remembered that the noise tape played a mixture of four male voices. Occasionally, individual words were intelligible, but it was impossible to follow any of the voices.

Procedure

For each judgment the noise was first turned to one of nine settings (1-9) on the volume control dial. Then the experimenter raised his hand, signalling the subject to listen to the loudness of the noise. When ready, the subject tapped a pencil, and the experimenter began to turn down the volume of the noise. As soon as the subject judged that the volume was half as loud as the original level, he tapped again. The experimenter immediately stopped turning the dial and recorded the reading. He then reset the dial to the level desired for the next trial. The procedure was analagous to a standard psychophysical scaling technique described by Woodworth (1938, pp. 505). However, in the present technique, the subject could not refer back and forth between the reference level and the level judged half as loud.

Each subject made six judgments for each of the nine dial settings. There were three ascending series of trials, during which two judgments were required for each original setting. Thus the sequence of dial settings (1,1,2,2,3,3,...9,9) was repeated three times. The procedure took about 25 minutes to administer to each subject.

Results

For each subject the mean judgments for the nine reference settings were computed. Individual consistency of judgment was good, except for reference settings eight and nine, where distortion altered the quality of the noise. Next, for each reference setting, the average judgment of all subjects was computed. Thus reference settings could be plotted against settings judged half as loud. The nine points were connected with a smooth curve, drawn by eye. Using this curve, one could estimate for any intermediate reference setting the setting that would be judged half as loud. In Table A each successive setting was perceived to be half as loud as the preceding one. The arbitrary perceived loudness value of 100 was assigned to setting 9, and subsequent perceived loudness values corresponded to lower dial settings.

Thus a new scale, from 0 to 100, representing perceived loudness, could be plotted against dial settings. The six points were connected with a smooth curve, drawn by eye. On this curve equal intervals of perceived loudness were marked off. The result, shown in Table B, was an interval scale of perceived loudness, in terms of the original volume dial settings. The interval of perceived loudness between noise levels was 12. Thus the volume dial was rescaled into an equal interval scale with eight levels.

Table A

Perceived Loudness for Volume Dial Settings

Volume dial setting	Perceived loudness value
9.0	100
6.3	50
3.7	25
2.3	12.5
1.3	6.3
0.9	3.1

Table B

Interval Scale for Loudness

Volume dial setting	Perceived loudness	Scale level
1.5	8	1
3.3	20	2
4.4	32	3
5.7	44	4
6.7	56	5
7.5	68	6
8.2	80	7
8.7	92	8

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THREE INDICATORS OF CHILDREN'S DEVELOPING ABILITY TO RECOGNIZE AND SOLVE COMPLEX PROBLEMS

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Background of the Study

Cognitive changes during the course of problem solving have been investigated in adolescents in two recent studies (Elias and White, 1969; Elias, 1970). The purpose of the present study is to look at these changes during problem solving in younger children whose ability to solve is just developing.

The first study presented problems in a series of trials. A subject was asked to guess which of two words was correct. As soon as he guessed, he was told which was in fact correct. Then he was shown two other words, and asked to guess between those. His task was to figure out a rule by which to choose correctly every time. For example, a problem in which the words "park" and "playground" were shown on the first slide, and followed by alternatives such as "river" and "lake", was solved by the rule, "the four letter word is correct". Once the subject succeeded in formulating the correct rule he found it easy to respond correctly on every subsequent trial.

High school students showed decreases in skin potential response and in latency of overt response at the time of solution of a problem. After solution they continued to respond to trials. Their performance was now correct, latencies were brief, and there was less skin potential response to each trial. It was inferred that the changes observed were caused by the cognitive act of solving the problem which, in this case, meant formulating a rule to guide future choices. Those subjects who were more skillful solvers showed more marked changes at solution than did less successful solvers (Elias, 1969).

In the second study several problems were presented in a continuous series of trials designed so that the introduction of a new problem was not evident from the procedure. An example of such a series is a number task in which the first rule to be formulated is "the even number". When the subject has demonstrated by a series of correct responses that he has found that rule, a slide is presented without pause in which two even numbers are shown. The subject should recognize the anomaly and be baffled by this slide. He can solve this new problem when he induces the rule "the two digit even number". The number of digits had varied irrelevantly at the first stage, so that the subject, in learning to choose by the even/odd distinction, learned also to ignore the number of digits. Now he must begin to notice it again if he is to induce the appropriate rule.

This design made it possible to measure changes in reactivity at the time of recognition of a problem as well as at its solution. High school students produced large increases in response latency and skin potential response at recognition of a new problem. Decreases in these measures at solution were also found, replicating the earlier finding. The decrease at solution was a gradual decline over several trials, whereas the increase at recognition was a sharp change at the trial introducing the new problem.

In the second study, skin potential responses were examined separately for the events of stimulus presentation, response, and feedback on each successive trial. The pattern of changes in response to each event was found to be consistent with an information processing interpretation. Larger changes occurred in response to events which could be inferred to be less predictable by the subject, and so brought him a large amount of new information. It was inferred from this study that when one finds oneself faced with a problem in which one is uncertain of how to respond, one enters a physiologically and cognitively labile state which can last until the problem is solved and uncertainty is reduced. Perhaps this state is a prerequisite for the kind of complex learning being investigated.

The present study started from this point. A reliable pattern of reactivity having been found in subjects who were physiologically adult, the question arose of emergence of the pattern during development in younger children. If the labile state is associated with this kind of complex learning, then its emergence in development might coincide with emergence of the ability to solve complex problems.

This chapter will be concerned with drawing the three studies together by considering them in terms of an information processing approach to complex learning and to its development in the growing child.

The Object of Study

Let us begin by developing more fully the view of complex learning being studied. The phenomenon was described by Bruner, Goodnow, and Austin (1956). "Having mastered the distinction between odd and even numbers, it is a feat to remember what it was like in a mental world where there was no such distinction...Moreover the transition experience between 'not having' the distinction and 'having it' seems to be without experiential content... It is, if you will, an enigmatic process and often a sudden process...Something happens quickly and one thinks one has found something... 'Now I understand the distinction, before there was nothing, and in between was only a moment of illumination'" (p. 50). It is this transition from "not having" to "having" a concept which will be termed complex learning in this study. The adjective "complex" distinguishes learning by concept attainment from the paradigms of conditioning or simple discrimination learning. Bruner's description invokes a sense of magic which, I think, accurately reflects the sensation of sudden insight. What changes in that "moment of illumination"? The purpose of these studies is to try to shed some light on the "enigmatic process" which seems to be an important phenomenon of complex human learning.

Bruner used the method of subjective report to describe the internal process of learning in this passage. What he called the "moment of illumination" in his subjective terminology is labelled here as "the cognitive event of solution". The event of solution must be preceded by an "event of recognition"; a moment at which one becomes aware that one has a problem. The object of this study is a postulated labile period bounded at its beginning by the internal cognitive event of recognition of a problem and at its end by solution.

Three indicators of these internal events are referred to in the title of the paper. They are performance, latency of overt response, and amplitude of skin potential response.

The logic by which these three measures can be taken as indicators of cognitive processing during problem solving is as follows. The measures have been found to vary in predictable ways during the process of working on a problem. Russian work on the orienting reaction has shown consistently a relationship between these same variables and the uncertainty of a situation or its unexpectedness for a subject. Information theory offers a model for assessing the amount of information conveyed by a message in terms of its uncertainty or unexpectedness for a subject. If one can identify certain occurrences during problem solving as being particularly unexpected, one may be able to infer what was expected by the subject; what was taking place in his cognitive processing. Evidence will be presented to support the claim that response latency and skin potential response do indicate the amount of information conveyed to a subject by an occurrence, and that therefore inferences may be drawn from them about the structure of cognitive processes.

Indicators of Cognitive Processing

Changes during Problem Solving

There is evidence from a number of sources to support the claim that reactivity does change during the course of working on a problem, so that a labile period exists between recognition and solution of a problem.

The beginning of the labile period at recognition of anomaly is consistent with Russian findings on what they call the Orienting Reaction (OR). They have given that name to a complex of responses which occurs when a subject notices a novel or attention-getting event in the environment. The reaction is composed of a variety of responses in different body systems. The head and eyes move to focus on the eliciting stimulus. Ongoing activity ceases. Characteristic responses occur in EEG and in the electrodermal and cardiovascular systems (Berlyne, 1960; Lynn, 1966). Sokolov (1963), who studied the physiological response systems intensively, commonly used simple stimuli such as a flash of light or a tone. He found large ORs to initial presentation of a stimulus followed by habituation to regular repetition, with restoration of the large responses to novelty or any sort of change in the repeated pattern. The phenomenon of a sudden increase in response size was found to occur strongly to anomaly at the introduction of a new problem in the second study of the three under consideration. The increase was recorded in electrodermal response and in latency of overt response but did not occur in heart rate.

The labile period has been found to continue during problem solving, in contrast to the rapid diminution of response amplitude which occurs to simple repetition of stimuli. Lynn (1966) points out that such diminution fails to occur if the stimulus is conditioned or has particular significance for the subject. The phenomenon is shown clearly only if one divides learning trials into those before and after the last error. When this is done, high reactivity until the trial of last error is followed by the expected decline. Germana (1968) reviewed the literature for GSR, EEG, and heart rate. He postulated an activational peak at the time of solution, with reactivity increasing thereafter. GSR and EEG showed the peak. Heart rate studies were few and not clear. I reviewed GSR studies by Kintsch (1965), Obrist (1950), Germana and Pavlik (1964), Grings and Lockhart (1966), and Andreassi and Whalen (1967) in my qualifying paper (Elias, 1969). Their graphs of GSR change at solution were copied in that paper to show the presence of the peak at solution in a number of different learning situations. I concluded that the decrease after the peak was a stronger effect than the rise before it. Kintsch's GSR data showed particularly clearly, in a study of nonsense syllable learning, high amplitude variable responses until the trial of last error followed by a drop to much smaller responses.

The same pattern can be found in studies of response latency in studies during learning when trials are divided at the trial of last error. Kintsch (1965) also recorded this variable and found long latencies until the trial of last error, and then a rapid diminution. Graphs were copied in my qualifying paper from Kintsch; Erickson, Zajcowski and Ehmann (1966), Millward (1964), and Williams (1962) to show the pattern. Here, again, the striking effect is the decrease after solution rather than a rise beforehand. The two papers which show pre-solution responses (Erickson et al. and Millward) show long latencies throughout the period before solution. Other studies have also found shorter latencies after solution (Siegel, 1964; Schlag-rey, Groen, and Suppes, 1965; Peterson, 1965). The activational peak with its characteristic large decline after solution was replicated in my second study in both electrodermal response and latency.

These studies are diverse in their learning tasks and measurement techniques. Considering those differences, and considering the complete independence of the two measures of electrodermal response and latency of overt response, it is striking to see how similar the graphs look from each study. Responses are large and latencies long before solution and diminish consistently after it.

It can be concluded from these findings that the variables of response latency and electrodermal response do vary in predictable ways during problem solving. They increase at recognition and decrease at solution. The phenomenon of a labile period between recognition and solution occurs in a variety of learning tasks.

Response to Unexpectedness

Evidence for the phenomena of the labile period has been presented. The next question to be considered is how one may interpret such phenomena. It has been claimed above that they can be interpreted in terms of the unexpectedness of occurrences for a subject or his uncertainty about an outcome.

Many of the Russian OR studies dealt with response to simple external stimuli such as light, sound, or cold, so the OR has come to be associated with objective stimulus parameters. However, the Russian studies also abound in references to the occurrence of OR to changes of all kinds in the stimulus such as change of order, change of sequence, change of pattern in any way; in short to any change which is surprising or unexpected (Berlyne, 1960; Lynn, 1966; Duffy, 1962). OR is also affected by conditioning of the stimulus, verbal instruction, or a requirement to respond behaviorally (Sokolov, 1963; Leontiev, 1961). These phenomena have led authors to conclude that the OR must be related to the unexpectedness of an occurrence for a subject as well as to its physical characteristics (Berlyne, Lynn, Duffy).

It seems plausible to pursue the reasoning that led to these conclusions, and to hypothesize that the OR may include components which will serve as our needed indicators of the unexpectedness of an occurrence for a subject. An anomalous slide introducing a new problem is obviously unexpected by a subject. Trials during the period of working on a problem but before solution can have unexpected outcomes. After solution, however, the subject is much more confident of the outcome of each trial, so his uncertainty is reduced, and he is never surprised by an outcome which he did not expect.

Information Theory Model

Some measures of the unexpectedness of an occurrence for a subject have been identified. We must now find a way to relate the concept of unexpectedness to the transmission of information if we are to interpret such measures in terms of information processing. Information theory offers such a model.

Let us consider the flow of information from an event to a subject as a message. Since the studies under consideration were not designed in a way to permit computation of the bits of information delivered by each event, information theory concepts are introduced only for their logic not for quantitative use. The subject is forced to make a choice between alternatives. He chooses on the basis of a guess with less than complete certainty of being correct. As soon as he has made his choice, the outcome--the correct choice--is revealed to him. The information conveyed to him by this outcome is a function of his estimate of its probability before it occurred. The information to specify an outcome whose probability is p, is the log to the base 2 of the reciprocal of the probability of the event. With equiprobable alternatives, $\log_2 1/p = \log_2 1/.5 = \log_2 2 = 1$. This unit of information is called a bit. The reasoning is as follows. If a subject has no reason to expect one outcome in a choice between two alternatives, his estimate of the probability of one choice being correct is about .5. Feedback reduces his uncertainty to zero, so the event has given him one bit of information. If, on the other hand, he has considerable confidence that he has figured out the rule by which to choose, his expectation of one outcome being correct is much higher. If it proves to be correct his uncertainty was reduced by much less than one bit. For example, if in his estimation $p = 7/8$, then $\log_2 \frac{1}{7/8} \approx .2$ bits. If, however, the unexpected outcome proves to be the correct one, that event delivers much more than one bit of information. If he estimates p to be 1/8, then $\log_2 \frac{1}{1/8} = 3$ bits. Therefore it can be stated that the information transmitted is inversely proportional to the individual's prior estimate of the probability of its occurrence. Stated more simply, the less he expects an outcome, the more information he gets from it.

The information theory model makes a logical case for different amounts of information to be transmitted by the outcome of a choice depending on how unexpected the outcome is to the receiver.

A few studies have been addressed to the question of finding behavioral response systems which vary as functions of the amount of information conveyed. Unlike the OR studies which have been considered above, these are designed explicitly for study of information content. Direct relationships have been found between the information content of a signal and CNV (contingent negative variation in dc potential from the scalp; Walter, 1966), evoked potentials of EEG (Sutton, Braren, Zubin, and John, 1965), reaction time (Hilgendorf, 1966), and pupillary dilation (Kahneman and Beatty, 1967). These studies all show that when the flow of information is deliberately measured, the measures vary with the information content of a message. These studies do not, however, deal with problem solving tasks nor with the measures to be used here. They are useful here in lending support to the argument that covert variables might plausibly be employed as indicators of the flow of information.

If some covert responses do co-vary with amount of information transmitted, then some specific predictions of changes in responsivity during problem solving can be made. Large responses to recognition of anomaly at the introduction of a new problem should occur because that unexpected event conveys a lot of information to the subject. Fairly large responses are to be expected during the period of uncertainty before solution, because the alternatives are roughly equiprobable during that period. Finally, a rapid decline in responsivity is expected to occur after solution has taken place and the subject's uncertainty about the outcome of each trial has been reduced. Thus, the labile period is predicted, bounded at its beginning by recognition of a problem and at its end by solution. The expected patterns are depicted in Figures 3 and 5. The skin potential pattern has been drawn with a slight rise before solving to show the activational peak predicted by Germana (1968) as well as a much sharper drop after solution. Only the post-solution decrease is expected to be a significant change.

In summary, a model has been presented from information theory by which the unexpectedness of an occurrence may logically be quantified and be related to the transmission of information. Empirical tests of the model show results which are not inconsistent with those of the present studies, but not directly comparable. Curves have been derived from predictions from the model for changes expected during the course of problem solving related to changes in a subject's uncertainty about outcomes.

Cognitive Processing Model

We come now to the final step in the argument. Having demonstrated that the measures under consideration do indicate the amount of information being transmitted by any one occurrence, it follows that one should be able to analyze a series of changes in these measures in terms of what is taking place in cognitive processing by seeing whether the large amounts of information are coming in at moments when one would expect them. In order to derive expectations, we need a model for the flow of information through the cognitive system during problem solving.

Such a model can be adapted from Miller, Galanter, and Pribram (1960). They contend that behavior is governed by plans. The unit of behavior is a feedback loop set to minimize discrepancy between an operation and criteria derived from a governing plan for what the operation should be. Criteria for _what should be_ constitute tests to which _what is_ can be compared. When the operation and the test are found to converge, one can exit from the unit of behavior. Such units can be combined in many kinds of organizations to form complex behavior sequences.

Miller _et al_. described problem solving as a search through a set of alternative hypotheses for one that satisfies criteria derived from a plan of search. If, as in my problems, the search plan included a criterion such as making a choice which always turned out to be correct, the problem would be solved when that criterion was met. The event of recognition of a problem can be interpreted as the moment at which a search plan takes over the executive function and starts to govern the cognitive apparatus. The event of solution is the time at which the search plan relinquishes control of the apparatus and the newly formed plan by which to respond takes over in its turn. The labile period is, then, the period during which the cognitive system is governed by a search plan.

In these terms the problem before us can be stated as an inquiry into the structure of a search plan. The content of possible search plans will not be dealt with here--for example, whether children are more likely to search by color or by form. There is a considerable literature in that area. However, the structure of a search plan is of interest.

One possible structure for search plans would be a linear sequence of units, each involving only one operation. This would be comparable to guessing on the first trial "it's the red one". If the color hypothesis is disconfirmed, one might guess on the next trial, "it's the square one" and so on. Only one dimension of variation is tested on each trial. If the tested dimension works, one would stay with it until it is disconfirmed.

Another search plan might involve a much more complex hierarchical arrangement of units. At the top of the hierarchy is an overall plan to find a solution to a problem. Units of behavior including operations and tests are nested under the superordinate plan. This organization makes possible a recursive program for processing each trial. Several test-operate units are fitted together in a way which is written in fortran as parentheses nested within parentheses. It is only possible to process information in such a way if one has a firm notion at the opening of the first paragraph of the endpoint he wishes to reach at its close. Only then can he keep his logic clear while handling several variables nested within it. Such a plan has a tight integrated structure dominated by the goal of problem solving unlike the loose chain-like structure of the first plan. These two models for search plans are highly speculative. An infinite variety of other such plans is conceivable.

By contrast to these postulated structures of search plans, a child faced with the task of solving problems by responding to trials in series can behave according to another sort of plan. It could be called simply a response plan. It consists of merely responding to trials without any attempt to solve a problem. Its goal presumably is to be obedient, to please the Experimenter, or to please oneself. A subject can behave in conformity with this plan by position responding or by any games or patterns of his own devising as long as he presses a window whenever a choice between two pictures is presented.

There are two ways to exit from any sequence of behavior including problem solving. One is by convergence between tests (what should be) and operations (what is). In the case of solving problems, to exit by convergence is to find an adequate solution. The other way is by means of a stop rule; a rule built into the governing plan which provides for exit without convergence of tests and operations in order to avoid an endless feedback loop. The possibility of exit from a problem by a stop rule rather than by solution is of interest because it will come up in analyzing the data later in this paper.

The notion of the stop rule was introduced from computer programming. It was found in programming that for every loop one had to have an explicit stop rule. Otherwise the program might get caught in the loop forever if the conditions for exit were not fulfilled. The possibility is not so obvious for human behavior because we seem to have implicit stop rules. If a companion leaves you, saying, "Wait here until I get back. I won't be long." and then fails to reappear, you wait for a while because the condition for exit from the situation (his reappearance) has not been fulfilled. If you were a computer you would wait forever unless a stop rule were written into your program. Being human, however, you do not wait forever. A stop rule sets in eventually which instructs you to exit from the situation. You then formulate another plan. You might go and look for your lost companion, or you might give up and leave in disgust. The computer analogy, by making the issue explicit, brings to our attention the existence of implicit stop rules in people and makes it possible to ask how they function for different situations or for different individuals.

The cognitive processing model offered postulated that information is being transmitted through the cognitive system in some kind of sequence of units of tests and operations governed by plans. Two types of search plans were suggested; one more complex and integrated than the other. A response plan was also suggested which called for responding without searching for a solution to the problem. The necessity of a stop rule was claimed for processing under the guidance of any plan.

Summary of Argument for Indicators of Cognitive Processing

It has been claimed that the measures of performance, response latency, and skin potential response can be used as indicators of the flow of information during the cognitive processing involved in problem solving. To support the claim, evidence has been presented to show that these measures do vary predictably during the course of problem solving. It has been shown that such changes have been interpreted as being related to the unexpectedness of an outcome. Unexpectedness has been shown to be related to the flow of information according to a model from information theory. Graphs have been presented depicting predicted changes in responsivity related to the amount of information transmitted. A labile period is expected while the subject is uncertain about the solution to a problem. It is expected to begin with a sharp increase in latency and in skin potential response size at the event of recognition of the problem and to end with decrease at solution. Some speculations about plans of search during problem solving have been offered. If the reasoning of this argument is accepted, one can then make inferences about the validity of the speculative information-processing models by measuring the three variables and seeing where they indicate periods of large and small information flow during processing.

Developmental Changes

Up to this point the discussion has been concerned only with adult functioning. A model has been proposed, and a pattern of mature functioning has been found which is consistent with it. The study to be described in this paper is the third of the group of three papers. It is concerned with the issue of the emergence of the mature pattern during development. Questions are immediately raised about each of our three indicators: performance, electrodermal response, and latency of overt response. What is the course of development of each response system? Can one infer that it indicates informational flow in the child as we have inferred for the adult? The literature bearing on these points is sparse, but can offer some clues on which to base expectations.

Development of the Two Covert Indicators

No studies of GSR or latencies during the course of learning in children were found.

There are a few reaction time studies in which electrodermal response was also measured. Grim (1967) varied preparatory intervals and recorded reaction times and GSR in first grade, sixth grade, and adults. He found no difference in GSR amplitude between children and adults but in first graders, unlike adults, reaction latencies increased with increasing preparatory interval. Sixth graders showed the increase less markedly.

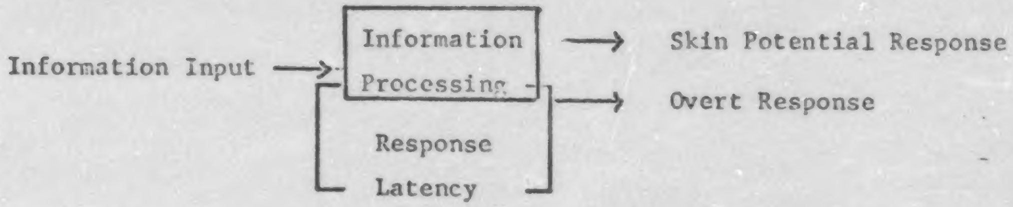
A study by Elliott (1965, 1966) compared 6 year olds to adults in the effect of varied incentive conditions on reaction time. Two years later he retested the same subjects, the children being 8 years of age by that time. He found a difference in skin conductance level at age 8 between incentive and non-incentive conditions. The subjects had shown no difference between conditions when they were 6. Elliott also showed faster overall reaction times for older subjects, which is a generally accepted phenomenon. He found that reaction time was related to skin conductance level for 8 year olds and for adults, but not for the children at 6 years of age.

A study by Kaplan (1968) attempted to relate cognitive development as measured by the Word Association Test to arousal as measured by skin conductance level in 5, 6, and 7 year old children. Since he did not record conductance at the time that cognitive measures were administered, there were no records of electrodermal changes during cognitive activity. He does show that 7 year old boys differed in skin conductance level between high and low arousal conditions. 5 and 6 year old boys and all girls showed no difference between conditions.

The measure of conductance level used by Kaplan and Elliott is not the same as the electrodermal measure, skin potential amplitude, used in my studies. Although skin resistance and skin potential response amplitudes have been found to correlate quite closely during active responding, the level variable is related not at all to response amplitude in skin potential, and only slightly in skin resistance (Willcott, 1958; Burstein, Fenz, and Bergeron, 1965; Gaviria, Coyne, and Thetford, 1969). This lack of relationship makes extrapolation to my study impossible. It is worth noting, though, that a hint is evident in Elliott's findings that the electrodermal system is not related to either cognitive or latency variables at age 6 and becomes related to both at age 8. Therefore, we can expect, with very little confidence, that performance, latency, and skin potential responses may come together at about age 7 and show the beginnings of the mature pattern during problem solving; that before that age they will be unrelated and erratic.

Relationships among the Three Indicators

There is no evidence bearing on the issue of whether the variables are true indicators of information processing in childhood, or on the issue of what importance differences between variables might have. Since the two covert variables bear different relationships to the performance variable, a diagram will help to clarify the reasoning by which their emergence may be interpreted.



Skin potential response and overt response, being two separate output systems from the same central processing, are correlated in the adult. If they are found to be not correlated in a young child, it could be due to a lack of connection between either output and the center, or to lack of functioning at the center. One cannot distinguish development in information processing capacity at the center from development in the output system. Electrodermal activity, being controlled by the automatic nervous system, is an indicator of a physiological support system which could follow a course of maturation separate from that of the cognitive system, although possibly vital to it. Response latency, however, is not a separate response system. It is simply the time which elapses between input and overt output. It can be conceptualized as an envelope for central processing, telling none of the details of what goes on, but surrounding the period of processing. Emergence of a correlation between skin potential response and performance can, on this basis, be interpreted as due either to maturation of one or both response systems or to beginning of information processing at a new level. The appearance of a correlation between response latency and performance should be due to new regularity in duration of information processing. The emergence of a correlation between skin potential response and response latency should be due to a developing connection between the autonomic support system and the information processing system.

A Developmental Model of Cognitive Processing

The variable of task performance, the third of our three indicators, is, of course, the usual measure of cognitive development. The literature is far more extensive but much of it is of little relevance here. Going back to the information processing model worked out for adults, one can consider how that might be elaborated to allow for developmental change in problem solving ability.

Kohlberg (1969) has formulated with some care the stage theory of development of Werner, Piaget, and others. He emphasized that "stages imply distinct or *qualitative* differences in children's modes of thinking or of solving the same problem at different ages" (p. 352). In the present study children of different ages will be asked to solve the same problems. So we should expect to find distinct or qualitative differences if the theory of stages in development is to be confirmed. He states further that, "Cognitive stages are hierarchical integrations... Accordingly higher stages displace (or rather reintegrate) the structures found at lower stages." (p. 353). In order to show the presence of stages one must show a discontinuity in development with a qualitative shift such that post-shift functioning encompasses as well as displaces pre-shift functioning. He does not discuss the relation of cognitive development to physiological maturation.

A qualitative shift resulting in hierarchical integration can be conceptualized by using the computer programming analogy. A comparable shift in programming would occur in shifting from a sequential program in which one operation is performed at a time in sequence to a nested program in which the same endpoint is reached in a more efficient and elegant way.

So let us propose a model of developmental stages as a loose sequential organization of information processing units followed after a transition by a nested hierarchy of the same component units. At the higher stage the individual units become integrated into the larger unit. Once the nesting concept has been grasped, it can be used for operations which cannot be performed sequentially.

White (1966) has argued for a shift from what I have called simple to complex learning at ages 5 to 7. He found that stimulus variation hindered kindergarteners' performance on a discrimination learning task but that neither second nor fourth graders were bothered by it. He concluded that the older children could induce a rule from selected aspects of the stimuli and use it as a guide as the situation varied. I am suggesting that they could subsume the problem of responding to a particular discrimination hierarchically under the larger problem of finding an over-riding generalization by which to respond. The kindergarteners were not yet able to do this and therefore were forced to respond to each trial in sequence as it came. Apparently if it varied from the previous trial it was regarded as a brand new problem. The shift from simple to complex learning can be seen as an integration of the earlier stage into a later stage in which both more generalization and finer discrimination are present.

Five year olds have been found to have difficulty in learning a task involving concept identification and transfer as compared with 11 and 13 year olds (Odom, 1966). Concepts were identified more adequately by older children in a comparison of kindergarten, first, and third graders using a card sorting task (Mitler and Harris, 1969). In discriminating photographic portraits, 5 and 6 year olds tended to over-discriminate, whereas 7-9 year olds and college students tended to over-generalize (Saltz and Sigel, 1967). Errors in learning a joint denial rule (not A, not B) dropped sharply after age 7 in a study of the development of rule learning using choices between cards whose patterns varied in a limited set of dimensions (King, 1968).

These studies concur with White's finding that a sharp improvement in ability to generalize or form concepts occurs at about age 7. They are consistent with the hypothesis that children shift from processing each event as a new and rather separate experience to processing each as an item subsumed under the task of solving a problem by finding a rule which binds the items together into a coherent whole. They do not, however, test that hypothesis.

A part of the model which was discussed earlier was the stop rule which is necessary to escape from endless loops in case of lack of convergence between operations and the governing plan. One might surmise that a creature whose lack of experience limited his ability to test a plan and whose lack of operational skills limited his ability to operate would need to rely particularly heavily on a stop rule. Moreover, in the developmental shift from sequential to nested organization of the structure of plans, the units are more loosely organized before the shift, and the end state less dominating. The plan might be stopped between any two operations. After the shift the integrated hierarchical structure, being tighter, may be less subject to the intrusion of a stop rule.

5 year olds were found to be limited to one way of sorting cards in a study of free classification, in contrast to 8 and 11 year olds who could re-sort the same cards several times according to different criteria. They were also less able to sort by criteria other than those they preferred (Kofsky and Osler, 1967; Mitler and Harris, 1969). These findings show a kind of rigidity in the 5 year olds which is strikingly different from older children. It can be interpreted in terms of a tyrannical stop rule which permitted the child to process the information coming in for

only a short time or in only one way, and which then clamped down, forcing termination of his involvement with the problem. Older children were able to inhibit the stop rule. They could then complete the task to their satisfaction, and exit by achieving congruence between the test and operate phases.

The developmental study was basically exploratory rather than a test of hypotheses. Its aim was to identify the emergence during childhood of the labile period found in adults during problem solving. From evidence from the three indicators taken together, more precise inferences about information processing can be made. Data were sought on the information processing issues suggested: that older children can inhibit a stop rule in order to continue working on a problem if they don't solve it at once; that they can respond to a problem as an integrated whole rather than as a sequence of trials. The presence of a developmental stage shift is suggested only if discontinuities can be identified which lead to the conclusion that a hierarchical integration has taken place at some point.

Method

Subjects

The subjects were 48 pupils at a public elementary school in Cambridge. They were residents of a working class neighborhood. Racially, they were white. Ethnically, many were of Italian, Irish, Polish, and Portuguese extraction.

16 subjects, half of them boys, and half girls, were drawn from kindergarten, second grade, and fourth grade. Selection was planned to get a broad spread of ability. The teachers were informally asked to suggest the best and worst students in their classes so that some top and some bottom students would be represented. No attempt was made to check the accuracy of the teachers' assessment. Children who were said by their teachers to be mentally retarded or severely emotionally disturbed were not selected. Three children who showed signs of anxiety in the laboratory were taken back to the classroom without being tested.

The subjects ranged in age from 5 years, 0 months to 11 years, 11 months. The Kindergarten range was 5-0 to 6-7 with a median of 5-6. Second grade ranged from 6-11 to 9-4, median 7-7. Fourth grade ranged from 8-11 to 11-11, with a median of 9-11.

Tasks

Tasks were adapted for young children from a design used previously with adolescents in my second study. An essential feature of the design was that several problems were presented in an unbroken series of trials.

After solving one problem, the subject was faced with another one without any change in procedure. This feature made it possible to study recognition as well as solution of problems.

Composition of the tasks in detail follows. It is important to distinguish the terms task, problem, and trial.

There were five tasks in all: an instruction task, a simple task, and three complex tasks. The tasks were separated by rest periods. The child was told when he was to start and when he had finished, so the tasks were clearly delimited for him. There were several problems within each task. The problems were not separated by breaks in time since each task ran without pause from one problem to the next. The subject could recognize distinctions between problems only in terms of content. Each task was made up of many trials. A trial consisted of presentation of two pictures, choice of one by the subject, and immediate re-presentation of the correct picture alone to tell the subject which choice was in fact correct. Trials ran in this traditional stimulus-response-feedback sequence throughout the task.

The substance of the tasks can best be presented in outline form:

Instruction task (from my purse)

Problem 1. Pictures: a coin vs. a key
Rule: The coin is correct.
note: in successive trials the coins and keys vary. A quarter, a dime and a penny are used, and photographed on different sides in different pictures. A house key and a car key are photographed in various positions. So the images in successive slides are never identical.

Problem 2. Pictures: The same quarter vs. the penny.

Rule: The quarter is correct.

Simple Task (adapted from traditional animal discrimination work)

Problem 1. Pictures: a black outline square vs. a similar circle.

Rule: The square is correct.

note: In this task the same square and circle appear in every trial so there is no variation in the figures.

2. Pictures: the same square vs. a square which is identical except for a diagonal slash across it.

Rule: The square without the slash is correct.

3. Picture: a square with horizontal bars vs. a square with vertical bars.

Rule: The square with horizontal bars is correct.

Form Task (adapted from Bruner Goodnow and Austin, 1956, Figure 1, p. 42.

Problem 1. Pictures: triangles vs. ovals.

Rule: Triangles are correct.

note: As well as varying relevantly in form, the figures vary in color--red or blue, in number--2 or 3, and in orientation--arranged horizontally or diagonally across the picture. They also vary in size, shape and rotation. Triangles may be equilateral, isosceles, right or irregular. Ovals may be wider or narrower than circles or perfect circles.

2. Pictures: Red triangles vs. blue triangles.

Rule: Red is correct.

3. Pictures: 2 red triangles vs. 3 red triangles.

Rule: 3 is correct.

4. Pictures: 3 red triangles arranged horizontally vs. 3 red triangles arranged diagonally.

   Rule: Diagonal arrangement is correct.

Inside task (adapted from Sharp 1969)

Problem 1. Pictures: Blue outline circles vs. similar rectangles

Rule: Circles are correct.

note: The figures may be big or little, one or two in a picture, arranged in varying parts of the picture and separate or on top of one another if there are two in the picture.

2. Pictures: a big and little circle together vs. 2 bigs, 2 littles, or a single circle.

   Rule: Big and little is correct.

3. Pictures: The little circle outside the big circle vs. inside it.

   Rule: Inside is correct.

Leaves Task (tree pictures cut from Brockman, 1968; shell pictures cut from Abbott, 1968)

Problem 1. Pictures: Leaves vs. shells

Rule: Leaves are correct.

note: Drawings of leaves and shells cut from field guides are photographed. Every particular drawing is different from the others in an unspecified number of dimensions such as kind of plant, number of leaves depicted, presence of buds, flowers, nuts or berries, color, etc.

2. Pictures: Broad leaves vs. needles

   Rule: broad leaves are correct.

3. Pictures: Palmate leaves (like a palm with major veins rayed out like fingers. example: a maple leaf) vs. pinnate leaves (one major vein running

down the middle of the leaf with side veins branching off. example: beech leaf).

Rule: Pinnate leaves are correct.

4. Pictures: Smooth edged leaves vs. serrate (having a notched edge like a saw blade).

Rule: Smooth edged leaves are correct.

The windows in which pictures appeared were side by side. The correct picture was presented in a fixed pattern of random alternation of right/left position. The randomness was restricted by a requirement of a change of sides within the first four trials of a new problem. Those aspects of a problem which had not yet become relevant were made to vary randomly between the correct and incorrect picture. In the Form task, for example, when triangles vs. ovals was the choice to be made, the triangles might or might not be red, 3 in number, or arranged diagonally. When the rule "triangles are correct" had been induced, the next problem was introduced by a slide showing a pair of pictures which could not be distinguished by that rule. They both showed triangles, one set red and one blue. Either might be 2 or 3 in number, and horizontal or diagonal. If the subject recognized the anomaly in this slide he must have induced the rule which it violated and he must now see that he had a new problem.

Solution of a complex problem came about by finding an invariant aspect of the varying figures and generalizing it into a rule which could guide choice in future trials. The rules were selected as ones which were comprehensible to children of the ages of the sample and were not related to school learning. No letters or numbers were used. In the Leaves task, technical terms are used here to describe differences between types of leaves which are visually quite distinct. Of course, the children did not have to know the terms in order to solve the problems. The criterion of solution was nine out of ten consecutive trials correct. If a subject failed to reach criterion in 20 trials, he was told the rule and then given 10 more trials on which he could be correct if he comprehended the rule. In this way, he almost always had been correct 10 times before receiving an anomalous slide signalling a new problem.

The focus of interest of the study was on the complex problems. The simple task, in which the figures did not vary, was presented as a contrast. Its problems could be solved by identification of the correct figure rather than by rule induction. It was expected that all the children would be able to solve the simple problems.

The Instruction task was given at the beginning to teach the subject about the procedure. It served to train him on the kind of response required, to show him the feature of anomaly at introduction of a new problem and to serve as screening for children who could not do the tasks.

In summary, the complex tasks presented several problems in a continuous series of trials consisting of stimulus, response, and feedback. Each problem was solved by induction of a rule from an invariant aspect of varying figures by which to choose correctly. If a child did not solve a problem, he was told the rule, and then went on from there. Within a task, each successive problem involved identifying a sub-set of a set of figures which had previously been found to be correct. The problems were not planned to be progressive in difficulty, but to be approximately even. The simple task, by contrast, was planned to be soluble by every child in the sample. It consisted of traditional two choice discrimination problems.

Apparatus

The apparatus for the study consisted of three parts connected by Grason-Stadler series 1200 programming equipment. The parts were a slide projector, a response box, and a Grass model 7 polygraph.

The projector back-projected slides onto two ground-glass windows set in a vertical panel in the response box. The slide for each trial contained two figures set far enough apart so that each showed in one window. Each slide was followed by a feedback slide showing only the correct figure for that trial. Ten different pairs of slides were made for each complex problem. When more than ten trials were needed, the slides were recycled.

As the subject sat at the response box, he saw two windows in front of him. They were set in a vertical panel inset deep in the box, so that when he leaned in, his field of view was confined by the sides of the box. He chose one of the two pictures projected on the windows by pressing that window. The windows were mounted on springs so that they could give a little when pressed, closing a switch. Pressing the window caused the slide projector to advance. The subject was thus informed of which picture was in fact correct.

The polygraph was connected to the slide projector and response box via the Grason- Stadler modules. The events of slide onset and window-press response were marked on its paper record. Response latency was measured as the distance between these marks on paper travelling at 3 mm. per second. The experimenter marked each trial manually as correct or incorrect as it occurred. She kept count of correct trials until the criterion of 9/10 was reached. She could then move on unobtrusively to the first slide of the next problem.

The polygraph also recorded skin potential activity through a dc pre-amplifier from silver - silver chloride cup electrodes. One electrode was attached to the palm of the non-dominant hand. The reference electrode was placed on the dorsal surface of the forearm. A flat plate EEG electrode was applied to the ventral surface of the forearm as a ground. The skin was prepared by vigorous rubbing with rubbing alcohol on a paper tissue. Electrodes were then applied to the skin and fastened with Scotch tape. The tape was an unconventional addition which was found to be both effective at holding the electrodes and reassuring to the subjects because it was familiar.

The subject's wiggle in his chair was recorded on the polygraph through a ramp integrator from a transducer made from a phonograph cartridge which was taped to an air-filled plastic cushion on which the subject sat.

Procedure

The study was conducted in a small room in the school. The room was wired and fitted up as a laboratory. Each child was brought to the laboratory for two sessions, in most cases on consecutive days. He was told that gadgets were going to be put on his hand and that he was going to play a guessing game. The subject was seated at the response box and electrodes were applied. This took about five minutes. The procedure was then explained by giving the Instruction task. The subject was asked to make a choice between pictures of a coin and a key. He was told the meaning of the feedback slide. Then he chose between pictures of a different coin and key. After a few trials he was led to generalize to the rule that the money was always correct. He was then run to 9/10 correct without prompting. Next he was shown an anomalous slide in which both windows showed coins. After learning the rule that the quarter was correct, he was run to criterion on that problem.

After the Instruction task, he was given the simple task, being told only that the pictures would be different, but the procedure similar. That was followed by a one minute rest period during which electrode placement was checked and slide trays were changed. Next, he was given one of the three complex tasks according to ordering determined by a latin square. Then electrodes were removed and, after being asked to come back the following day, he was taken back to his classroom.

The next day when the subject returned, electrodes were applied and he was reminded of the procedure. The remaining two complex tasks were administered with a rest period in between. Each session lasted about one half hour.

M and M candy was provided during the sessions. A gift was offered at the end of the first session and given at the end of the second. Gifts were fake beards, mustaches, et al. for boys and toy watches or jewelry for girls. The reason for giving candy and gifts was to counteract anxiety about the procedure and to give children a positive feeling about returning to the laboratory. In fact, being excused from the classroom and playing a new game seemed to be adequate incentives but the gifts served as thanks to the children for participating.

Scoring and data reduction

The data recorded consisted of the three indicators referred to in the title: performance, skin potential, and response latency, and in addition a measure of wiggle in the chair. The wiggle measure was not found to relate to problem solving on inspection of the records so it was not analyzed further.

All records were scored for the three indicators.

Performance scores consisted of: 1. How many complex problems each subject had solved out of 11 problems given. 2. Of those not solved, how many showed that he performed correctly after being told the answer. 3. In solved problems, how many trials took place before the beginning of the run of correct trials to criterion.

Response latency was scored by measuring millimeters of paper travel at the rate of 3 mm. per second between the mark for slide onset and that for window-press response. Scores were transformed by a log transformation in order to normalize the distribution.

Skin potential responses were measured in three ways: 1. The maximum pen deflection during the six seconds after the subject pressed the window to respond was measured. That period was used because it had been found in my earlier studies to contain the largest response to a trial. It had also been found in my second study that the diminution in response size after solution of a problem occurred primarily at that time. One might call it the "solution" measure. 2. The large response to anomaly at the introduction of a new problem, however, did not occur after the window-press. It came at the beginning of a trial in response to the onset of the anomalous slide. For this reason, the trials at the beginning of new problems were measured not only after window-press, but also after slide onset. Thus, the "recognition" measure consisted of the maximum pen deflection during the whole period of 4 seconds after slide-onset and 6 seconds after window-press. 3. The third skin potential measure was a frequency count of responses to slide-onset. As mentioned above, responses occurred to slide-onset at recognition of an anomalous or unexpected slide. In older children and adolescents, noticeable responses to the onset of a new slide were otherwise rare. It was noted, however, in inspection of the records that they seemed to appear much more frequently and erratically at other times in the records of the youngest children. Consequently, a frequency count was done on the occurrence of responses to slide-onset during trials after solution had taken place, when one would not expect them to appear. For this purpose, a response was counted present if the pen deflection reached a peak of upward deflection and started down during the period between the marks of slide onset and window-press response. Scores for the recognition and solution measures were transformed into standard scores (z scores) in order to make scores of different subjects comparable.

To summarize, three variables were scored. Performance scores were number of complex problems solved and maximum number of trials before solving for each subject. Latency scores were log transformations of distance of paper travel at 3 mm per second from slide presentation to response. Skin potential solution score was mm pen deflection during the six second period after the subject's overt response at a setting of 5 mv. per cm. The recognition score in skin potential was mm pen deflection during the longer period of four seconds after slide presentation and six seconds after the subject's response. A third score for the skin potential variable was a frequency count of responses to slide presentation after having solved. For this purpose, responses were counted if they showed a peak of upward deflection during the period between slide presentation and response. Size of the deflection was not considered for the frequency count.

Results and Discussion

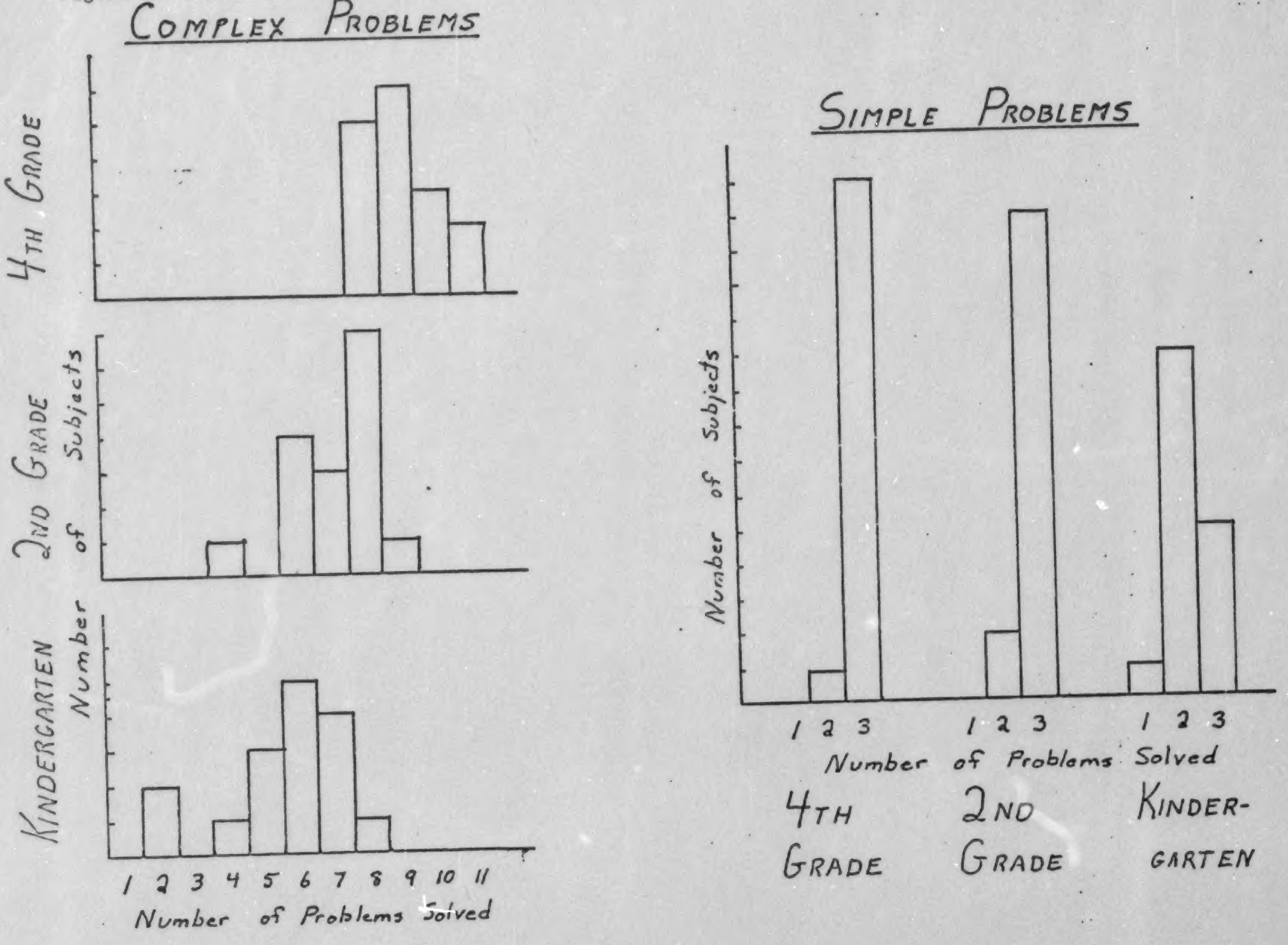
Analysis of the data was aimed at answering several questions. The first was to see if children of these ages would show the labile period by patterns of increased reactivity at recognition of problems and a corresponding decrease at solution. The next questions were whether differences in skill or sex within an age group were related to differences in the pattern of reactivity. After comparisons were made for children within one grade, differences between ages were examined. Next, relationships among the three measures were investigated. Finally support was sought from the findings for inferences about cognitive processing and a stage theory of cognitive development.

The Labile Period - Three Indicators

Performance

Before looking into results on the children's reactivity, we must look at the performance measure. Solution is defined by error-free performance, so this indicator sets the bounds on the labile period. Performance results show a continuous improvement in number of complex problems solved with age as might be expected (figure 1). Contrary to my expectation, all children did not solve all the simple problems (figure 1). The complex problems did turn out to be well planned in difficulty for the group of children. There is no evidence that subjects found them all too easy or too hard. The different problems did not

Figure 1. Number of Problems Solved.



COMPLEX PROBLEMS

SIMPLE PROBLEMS

prove to be equal in difficulty, however. Some were solved by very many children, some by very few. But none was solved by every subject and none was failed by every one. I have not attempted to analyze the subjects' responses to the content of specific problems.

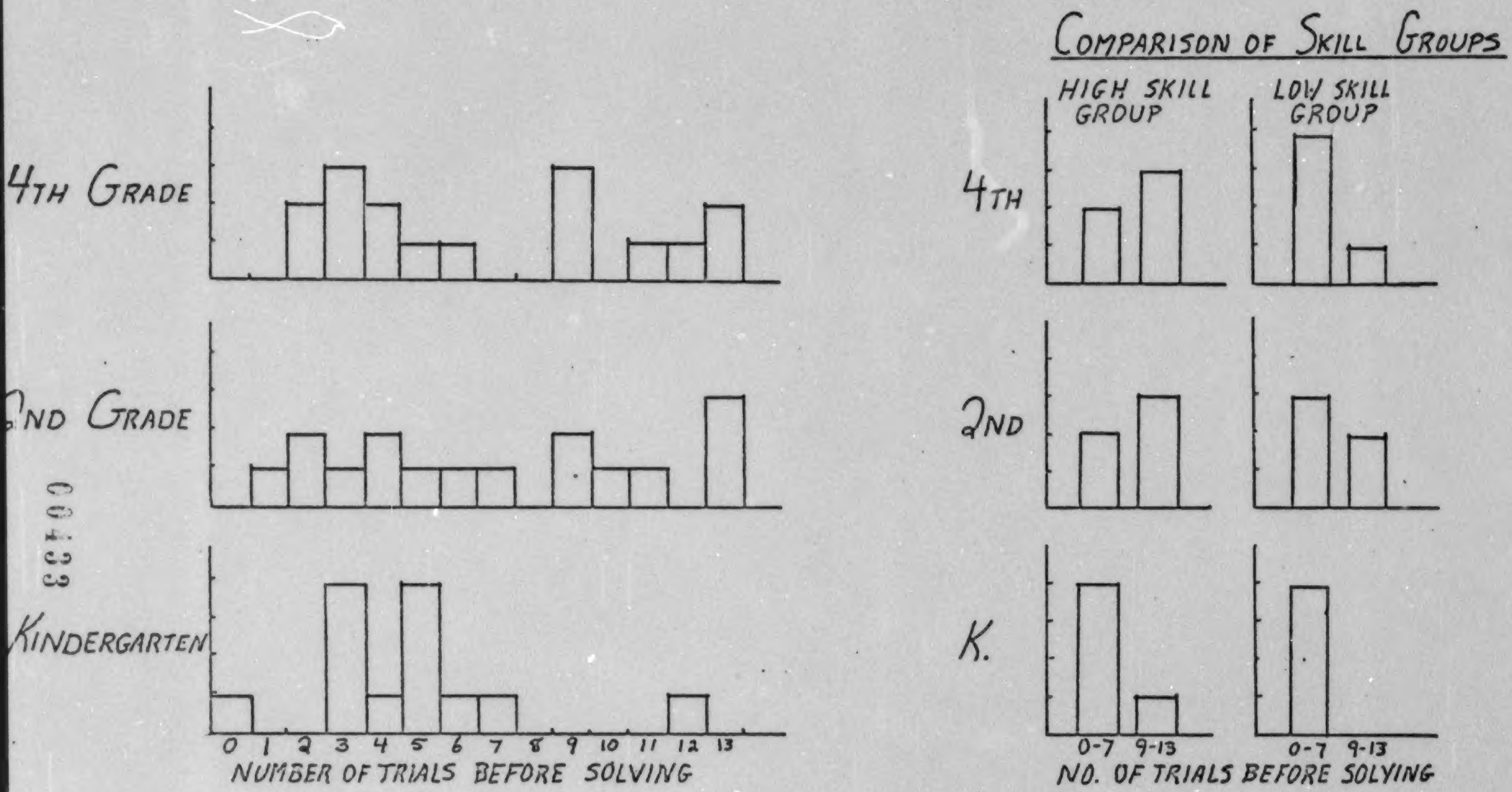
When maximum number of trials before the event of solution for each child was examined, a continuous improvement with age was not found (Figure 2). Instead, kindergarteners solved quickly or not at all, while almost half of the 2nd graders and 4th graders could solve after a longer series of trials. The finding contradicts the common-sense expectation that younger children would solve more slowly. It seems as if the 5 year olds must think of the correct rule almost immediately if they are to succeed in solving, whereas older children may discard one or two possibilities which do not work before solving by the correct rule. Three kindergarteners were omitted from this analysis because the trial of last error could not be determined in their records.

Latency of Overt Response

We can now proceed to an examination of results pertaining to the labile period. It has been hypothesized that when a subject does not know which choice to make, he pauses before responding; his response latency is relatively long. When he is certain of which choice to make because he has figured out the rule governing the problem, he can respond more quickly.

Change at recognition. In order to document the expected change in latency at recognition of a new problem, responses to the first trial of each new problem were compared to those of the preceding trial in the

Figure 2. Maximum number of trials before Solving.



unbroken series. A change score was computed for each subject by subtracting the score for the preceding trial from the score for the anomalous trial. Of the total of 11 problems offered, three began at the beginning of tasks and could not be used, so each subject had eight recognitions of complex problems to be averaged. The null hypothesis would predict no mean change because chance differences between latencies on these two trials would average out to zero.

A marked increase in latency was found for all ages at recognition of a complex problem (Table 1, Figure 3). Matched t tests comparing the change scores with zero were all highly significant ($p < .001$). The change is depicted in Figure 3 as a steeply rising slope at all ages. No difference is evident between ages. At all the ages tested, the sharp increase in latency supports the inference that the subjects noticed the anomalous character of the slides introducing new problems.

It is worth noting in passing that the overall positioning of latencies on the graphs in Figure 3 shows the regular diminution of latencies with increasing age. This phenomenon is generally known and accepted as a developmental trend for children of these ages.

Change at solution. Decrease in response at solution is harder to pinpoint because in a two-choice paradigm one has a fifty percent chance of being right by chance. Therefore it often seemed that the experience of solution occurred on trials later than the one following the last error. For this reason four trials were averaged which were planned to surround the moment of solving. They included the trial before the last error, the last error trial, and the two trials following. The mean of these four trials was compared to the mean of the four trials immediately following which were all correct and occurred during the criterion run.

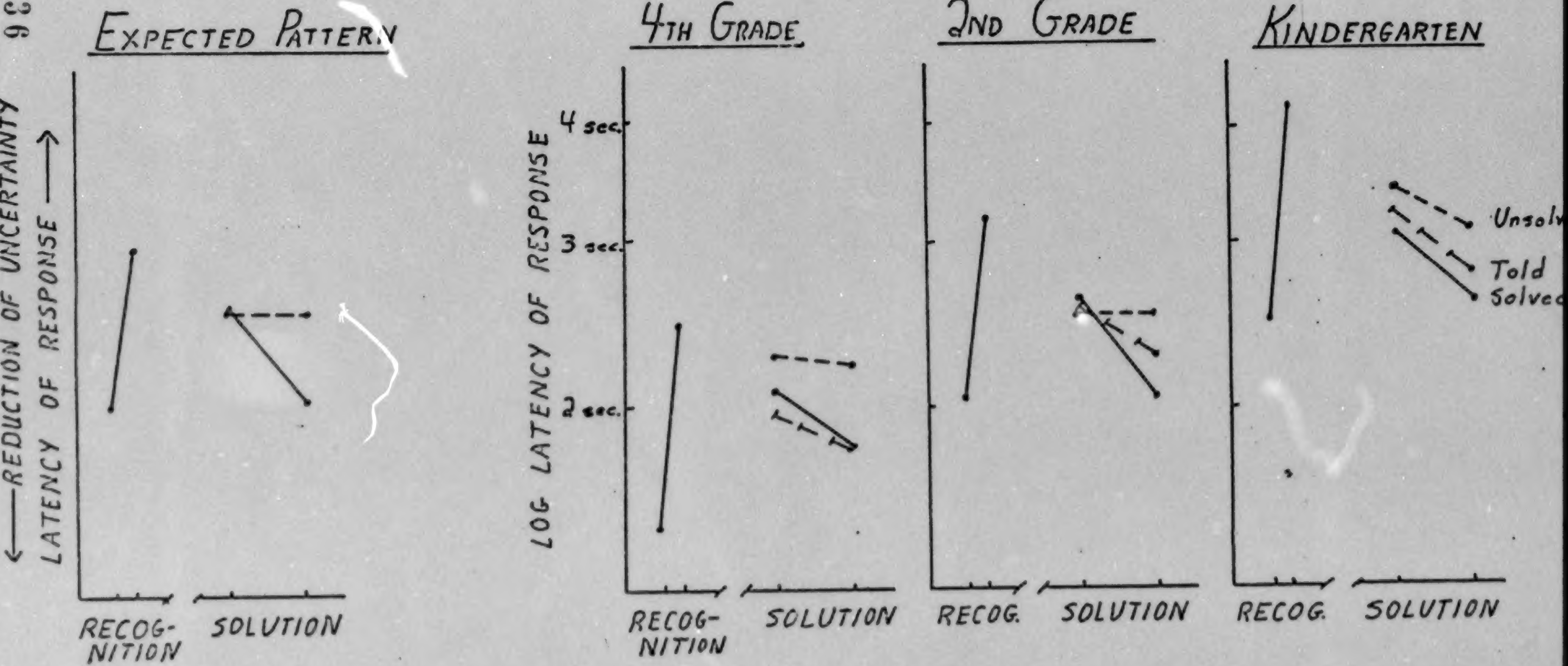
Table 1

Changes in response latency at recognition and solution of problems within school grades

Grade	Variable Description	Mean Change	sd	Var.	N	t-test	Sig.
4	Increase at recognition	.19	.08	.006	16	9.588***	p=0.000
	Decrease at solution	.06	.06	.003	16	3.983**	p=0.001
	Decrease in unsolved problems	.02	.06	.003	16	1.113	ns
	Decrease on being told	.03	.07	.005	13	1.575	p=0.141
	Solved vs. unsolved decreases	.04	.07	.005	16	2.440*	p=0.028
	Solved vs. told decreases	.01	.09	.009	13	0.485	ns
2	Increase at recognition	.19	.09	.008	16	8.227***	p=0.000
	Decrease at solution	.11	.13	.017	15	3.222**	p=0.006
	Decrease in unsolved problems	.00	.12	.014	16	0.118	ns
	Decrease on being told	.06	.12	.013	16	2.043	p=0.059
	Solved vs. unsolved decreases	.11	.19	.036	15	2.304*	p=0.037
	Solved vs. told decreases	.05	.16	.026	15	1.180	ns
K	Increase at recognition	.22	.14	.020	16	6.048***	p=0.000
	Decrease at solution	.06	.16	.025	15	1.445	p=0.170
	Decrease in unsolved problems	.05	.10	.010	16	2.151*	p=0.048
	Decrease on being told	.06	.10	.011	16	2.163*	p=0.047
	Solved vs. unsolved decreases	.01	.18	.031	15	0.178	ns
	Solved vs. told decreases	.01	.22	.046	15	0.149	ns

* $p < .05$
** $p < .01$
*** $p < .001$

Figure 3. Changes in Latency of Response at Recognition and Solution of Problems. Change at recognition is response to the first trial of a new problem as a change from the preceding trial. Change at solution is the mean of four trials after solution as a change from the mean of four trials surrounding the trial of last error. Change without solution is the mean of four trials as a change from the mean of the four preceding trials, in sequences in which solution did not occur. Spontaneous solution is contrasted with solution by being told the governing rule.



The difference between these means was taken as the change in latency at solution; the mean change score. Here again the null hypothesis predicted no change on the average.

Mean change scores were found for each subject by averaging his changes in up to four solved problems. It was necessary to use only those problems which were solved after the second trial in order that the trial preceding the trial of last error not be the recognition trial at the beginning of the problem. Since many problems were solved on the first or second trial, this restriction reduced the number of problems available for analysis, but 45 subjects provided change scores on at least one problem.

Fourth and 2nd graders showed the mature pattern of decreasing latency at solution ($p < .01$). The decrease was not significant for kindergarteners (Table 1). The solid lines at solution in Figure 3 depict the slope of the changes at solution for each age level. These results taken with the recognition changes show the expected increase at recognition and decrease at solution which bound the labile period. The period is identifiable at ages 7 and 9, but not yet at age 5.

Change without solution. The changes at solution were contrasted with comparable parts of unsolved problems which were expected not to show decreases. Unsolved sequences consisted of eight trials taken from problems in which the subject ran to 20 trials without solving. The exact eight trials to use was selected by matching to a solved sequence for the same subject. For example, if a solved sequence was used in which the last error occurred on trial 6, the sequence included trials 5-12.

Trials 5-12 of an unsolved problem were then chosen as an unsolved sequence for that subject. From one to four unsolved problems were averaged for a mean unsolved change score for each subject.

Since the unsolved sequences were by definition sequences before solution had occurred, the subject should be working on the problem and be in the labile state during that time. It is hypothesized that his latencies should be continuing to be long without any trend to increase or decrease. This was found to be the case for 2nd and 4th graders (Table 1). There was no significant change during unsolved sequences. Figure 3 shows the continued high level with little change in slope. Kindergarteners, however, did show decreasing latencies in unsolved sequences ($p < .05$).

If the observed changes at solution were really due to the internal event of solution, the change at solution should be significantly different from any change which might occur in matched sequences without solution. Comparison of decreases in solved versus unsolved sequences reveals such differences ($p < .05$) in the records of 7 and 9 year olds, but not in 5 year olds (Table 1). The conclusion can be drawn that for the older children, the labile state does exist and holds until solution; that the decrease at solution is due to the cognitive event of solving rather than to some other change over time. For 5 year olds, on the other hand, latencies diminished after the initial surge at recognizing a new problem whether or not the child solved the problem. The labile period began for them as for the others, but they could not maintain it. A decrease occurred over time independent of solving the problem.

Change on being told. Another set of trials was contrasted with those in which solution took place. These problems are referred to hereafter as "told" problems. They are problems in which the rule was told to the subject and he was then correct for ten trials. These problems were solved by the performance criterion but not spontaneously. It was expected that decreases in these problems would be similar to those in which solution was spontaneous. The told sequences were chosen to correspond to solved sequences. Two trials before being told were averaged with two trials afterwards. These four were contrasted with the four following trials. Up to four told sequences were averaged per subject to obtain his mean told change score.

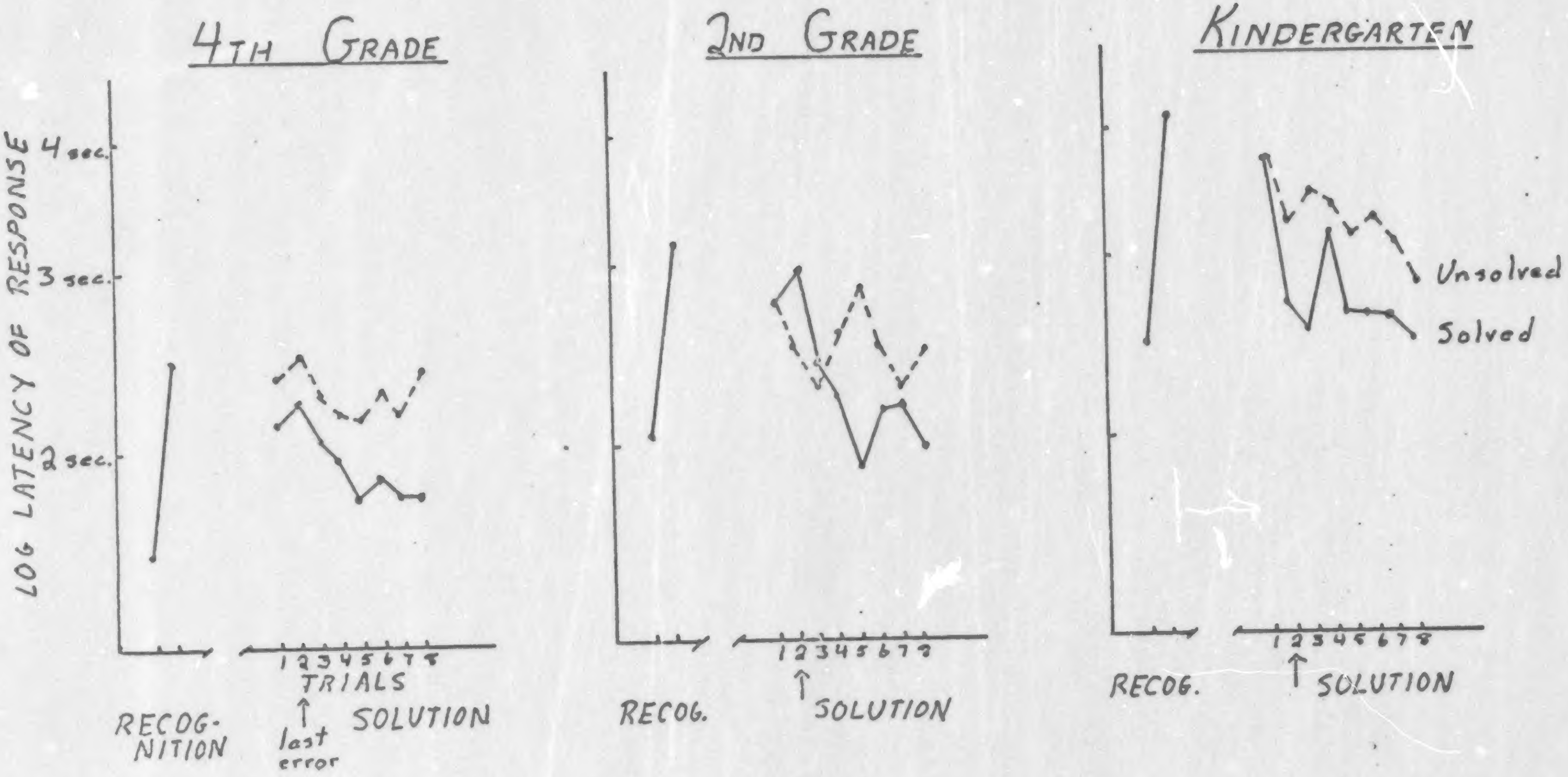
When they had been told the rule, latencies of 7 and 9 year olds tended to decrease but not so sharply as when they solved for themselves. The changes did not reach significance (Table 1). The told changes are seen as dotted lines in Figure 3 contrasting with the solid lines of spontaneous solution. Five year olds showed a decrease ($p < .05$) when told the rule. The slope of change (Figure 3) can be seen to be very similar to changes in solved and unsolved sequences. A comparison of the change at spontaneous solution with that at being told reveals no significant differences between the two conditions at any age (Table 1). These findings are consistent with expectations for 2nd and 4th graders. For kindergarteners, they reinforce the conclusion that those subjects' latencies diminish irrespective of the state of solution of the problem. Their pattern appears to be an increase in latency on recognition of a problem followed shortly by a decrease whether or not the problem is solved.

A more detailed picture of the pattern of solving is given by trial-by-trial graphs (Figure 4). The rise to an activational peak is not evident, but the post-solution decline can be seen at all ages. [illegible] 5 year olds showed an equivalent decline when they were not solving during the period in which older children maintained their long latencies.

To summarize the findings on changes in latency at recognition and solution, the labile period was found in 7 and 9 year olds. They showed increases in latency at recognition, continued long latencies until solution; at which point, the latencies diminished. For these older children unsolved sequences were significantly different from solved sequences, strengthening the inference that the post-solution decrease was related to the cognitive event of solving. When these children were told the rule instead of inducing it themselves, they tended to shorten the latency of their responses but not significantly. The expected pattern of lability during problem solving was present in these children.

The 5 year olds presented a different pattern. They produced increases at recognition as large as those of the older children, but long latencies were not maintained. Diminutions of about equal size occurred whether a problem was solved, told, or not solved. It can be concluded that the change at recognition shows that the latency measure does reflect cognitive functioning and the children did recognize anomaly in this situation. However, they did not appear to be able to maintain the labile state in trying to deal with the anomaly. Their pattern was one of a peak of latencies followed by decreases with or without solution. The decreases must have been due to something other than the act of solving the problem.

Figure 4. Trial-by-trial changes in Latency of Response.



Amplitude of Skin Potential Response

Indications of a labile period are also expected to be found in changes in amplitude of skin potential response. The expected pattern is similar to that for changes in latencies except that there is some evidence from Germana and others that during the period before solving, the size of responses will tend to increase instead of staying about the same as was the case with latencies.

Change at recognition. A change score was obtained as it was for latency, by subtracting the amplitude of the response to the trial prior to the anomalous trial from the amplitude recorded on the anomalous trial itself. A mean score for the change for each subject was computed. Group means were then compared by t test to zero change predicted by the null hypothesis.

Increases were found. They were significant in 4th grade ($p < .05$) and kindergarten ($p < .01$) but not for 2nd grade (Table 2). Figure 5 displays the changes graphically. Even in 2nd grade, a tendency to increase is apparent in the Figure.

Changes in solved, unsolved, and told sequences. The change scores were the same as those obtained for the latency variable. The mean of four trials after solution was subtracted from the mean of four trials surrounding solution, of which the trial of last error was the second. The same sequences were used for these analyses as for latency. T tests were performed on group mean change scores.

The expected decline after solution was found for 4th grade ($p < .05$), but not for the two younger groups (Table 2). Both 2nd grade and kindergarten produced non-significant increases instead of the predicted decrease

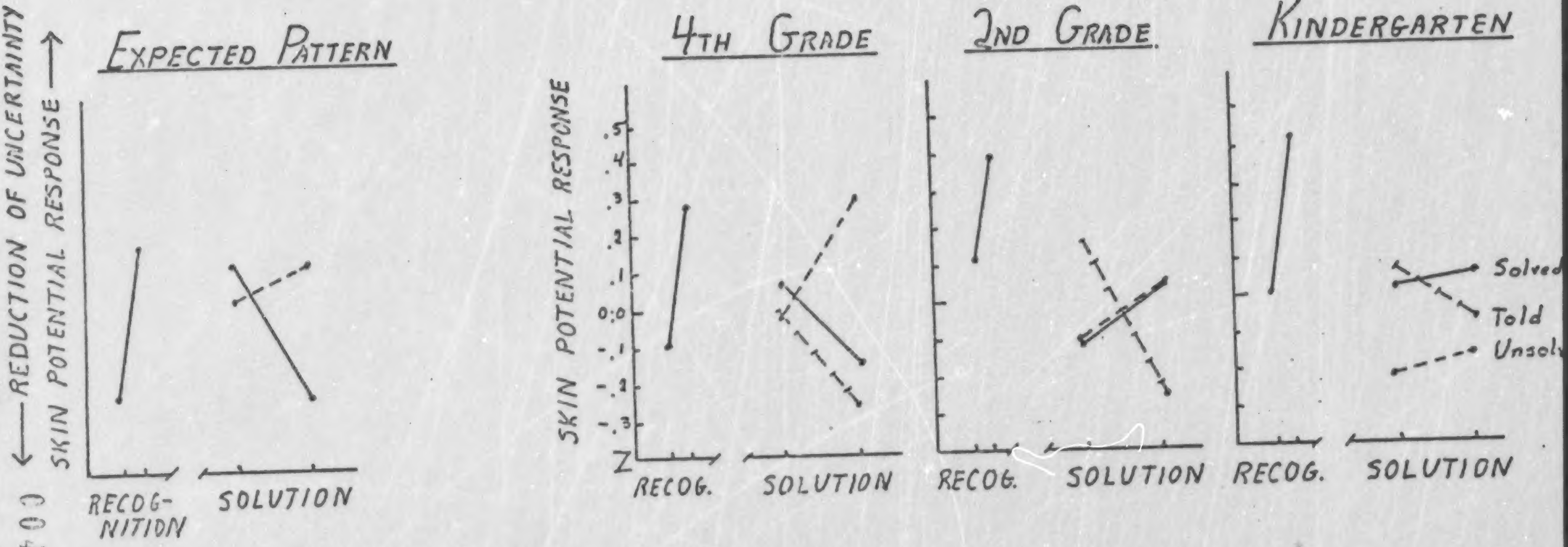
Table 2

Changes in skin potential response at recognition and solution of problems within school grades

Grade	Variable Description	Mean Change	sd	Var.	N	t-test	Sig.
4	Increase at recognition	.36	.60	.36	16	2.414*	p=0.029
	Decrease at solution	.24	.37	.14	16	2.554*	p=0.022
	Decrease in unsolved problems	-.32	.67	.45	16	-1.672	p=0.081
	Decrease on being told	.23	.56	.32	13	1.442	p=0.175
	Solved vs. unsolved decreases	.55	.73	.54	16	3.019**	p=0.009
	Solved vs. told decreases	-.06	.49	.24	13	-0.404	ns
2	Increase at recognition	.25	.60	.35	16	1.682	p=0.113
	Decrease at solution	-0.12	.49	.24	15	-0.961	ns
	Decrease in unsolved problems	-0.12	.45	.21	16	-1.022	ns
	Decrease on being told	.41	.44	.19	16	3.719**	p=0.002
	Solved vs. unsolved decreases	.01	.67	.45	15	0.058	ns
	Solved vs. told decreases	-.55	.66	.44	15	-3.204**	p=0.006
K	Increase at recognition	.38	.48	.23	16	3.112**	p=0.007
	Decrease at solution	-.03	.67	.45	15	-0.198	ns
	Decrease in unsolved problems	-.03	.26	.07	16	-0.456	ns
	Decrease on being told	.12	.37	.14	16	1.333	ns
	Solved vs. unsolved decreases	-.02	.82	.67	15	-0.075	ns
	Solved vs. told decreases	-.17	.71	.50	15	-0.929	ns

* $p < .05$
** $p < .01$
*** $p < .001$

Figure 5. Changes in Skin Potential Response at Recognition and Solution of Problems.



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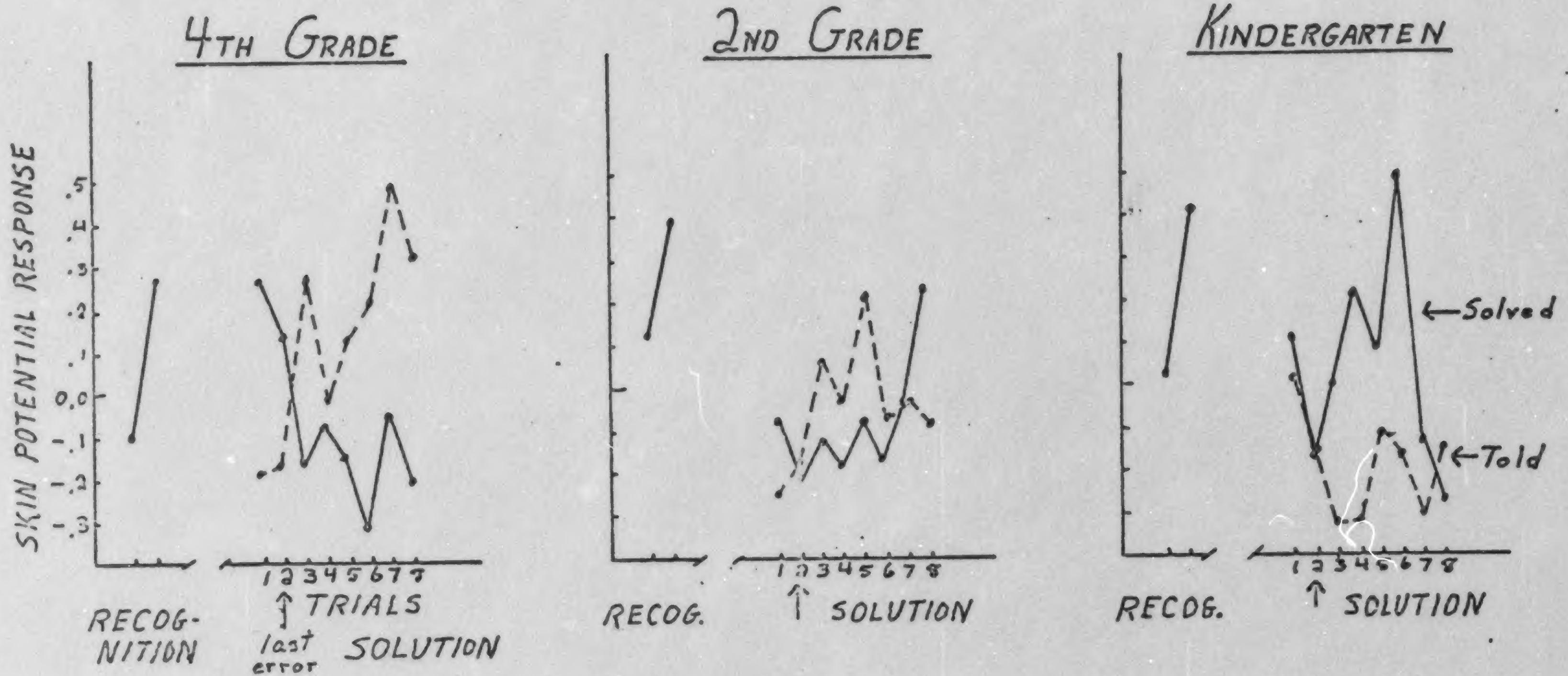
(see Figure 5). So only the 9 year olds exhibited the mature pattern of the labile period in the skin potential measure. Neither a significant rise in reactivity nor a significant decline was found in 7 year olds. Five year olds produced the increase at recognition, but not the post-solution decrease.

No significant changes were found in the course of unsolved sequences. Figure 5 shows a tendency for response size to increase, especially in the oldest group, when solution failed to take place.

When the subjects were told the answer, all ages showed a subsequent decline in reactivity. This was not a significant change for the oldest and youngest groups, but the 2nd graders produced a sharp decrease ($p < .01$) in this condition (Table 2). Thus, the 7 year olds, who did not decline on solving for themselves, did so strongly when they were told the rule. The occurrence is hard to interpret. I would only speculate that perhaps this equivocal finding is a sign of the emergence of the mature pattern, but that it is still unstable and erratic at this age level. At age 5, by contrast, the mean change in solved, unsolved, and told sequences was always close to zero. Kindergarteners' records showed erratic changes which cancelled each other out in the averaging. Such changes seemed unrelated to solving. As with the latency measure, the onset of a labile period is apparent at recognition but it must fade quickly in 5 year olds.

Figure 6 shows the detail of trial-by-trial changes in skin potential response size. A curve which might be seen as an activational peak was produced by the 4th grade, but it did not peak at the trial of last error so it is not a clear replication of Germana's (1968) hypothesis. The

Figure 6. Trial-by-trial Changes in Skin Potential Response at Recognition and Solution of Problems.



post-solution decline is evident for 4th graders, and for 2nd graders when told the rule. Kindergarteners exhibited erratic variability.

In summary, the mature pattern of reactivity in the skin potential measure was found only in 9 year olds. They produced the expected rise at recognition, continued high and rising amplitude while working on the problem, and the post solution decrease. In 7 year olds it may have appeared in equivocal form with a rise but not to significance at recognition, and a decrease after having been told the rule, but not after having solved spontaneously. In 5 year olds, the onset of the labile period appeared, but it was brief. There was no change in response size associated with the cognitive event of solution.

Skill Differences

An attempt was made to separate the effects of skill differences from those of age. Skill is defined by performance on the tasks in this study without reference to any external measure of intelligence or school achievement. The five subjects who solved the most problems in their grade comprise the high skill group. The five who solved the least make up the low skill group. Looking at Figure 1, it can be seen that the most highly skilled kindergarteners and the least highly skilled 4th graders both solved eight problems. On the basis of similarity in age, one would expect highly skilled kindergarteners to show responses like low skilled kindergarteners. On the basis of brightness, they might be expected to be like highly skilled 4th graders. On the basis of performance, they should resemble low skilled 4th graders.

Analyses of covariance were performed to look at the effects of skill on the two measures with the effects of age partialled out. The results were negative. $\underline{F} < 1.00$ for latency changes at recognition, solution, and unsolved sequences. $\underline{F} = 2.56$ ($p < .12$) in sequences in which the rule was told to the subject. In skin potential, $\underline{F} < 1.00$ for changes at recognition and solved and told sequences. $\underline{F} = 2.51$ ($p < .13$) in unsolved sequences in the skin potential measure. It was concluded that mean changes did not differ significantly between high and low skill groups.

Detailed comparisons were then made on the groups of five high skilled and five low skilled subjects within each grade. The groups were too small for significance testing but by looking at similarities, at least one can make guesses about whether skill or age differences are the primary causes of differences between groups.

In the performance criterion of number of trials before solving, high skill subjects at each age tended to solve later than the low skill groups of the same age (Figure 2). The only kindergartener whose maximum number of trials before solving was above seven was in the high skill group. So skill seems to be related to the ability to solve after a delay, but age looks like a much stronger determinant than skill.

The latency findings for skill groups showed few striking differences between the high and low groups (Figure 7). High skilled subjects tended to show the pattern of the labile period more strongly than low skilled members of the same age group. Note (Figure 7) the larger decreases at solution for high skilled 4th and 2nd graders, and the tendency for high skilled kindergarteners to hold long latencies better when they fail to solve.

Skin potential response changes were also similar for the most part, considering the greater variability in general of this measure (Figure 8).

Figure 7. Latency of Responses of High and Low Skill Groups during Recognition and Solution of Problems.

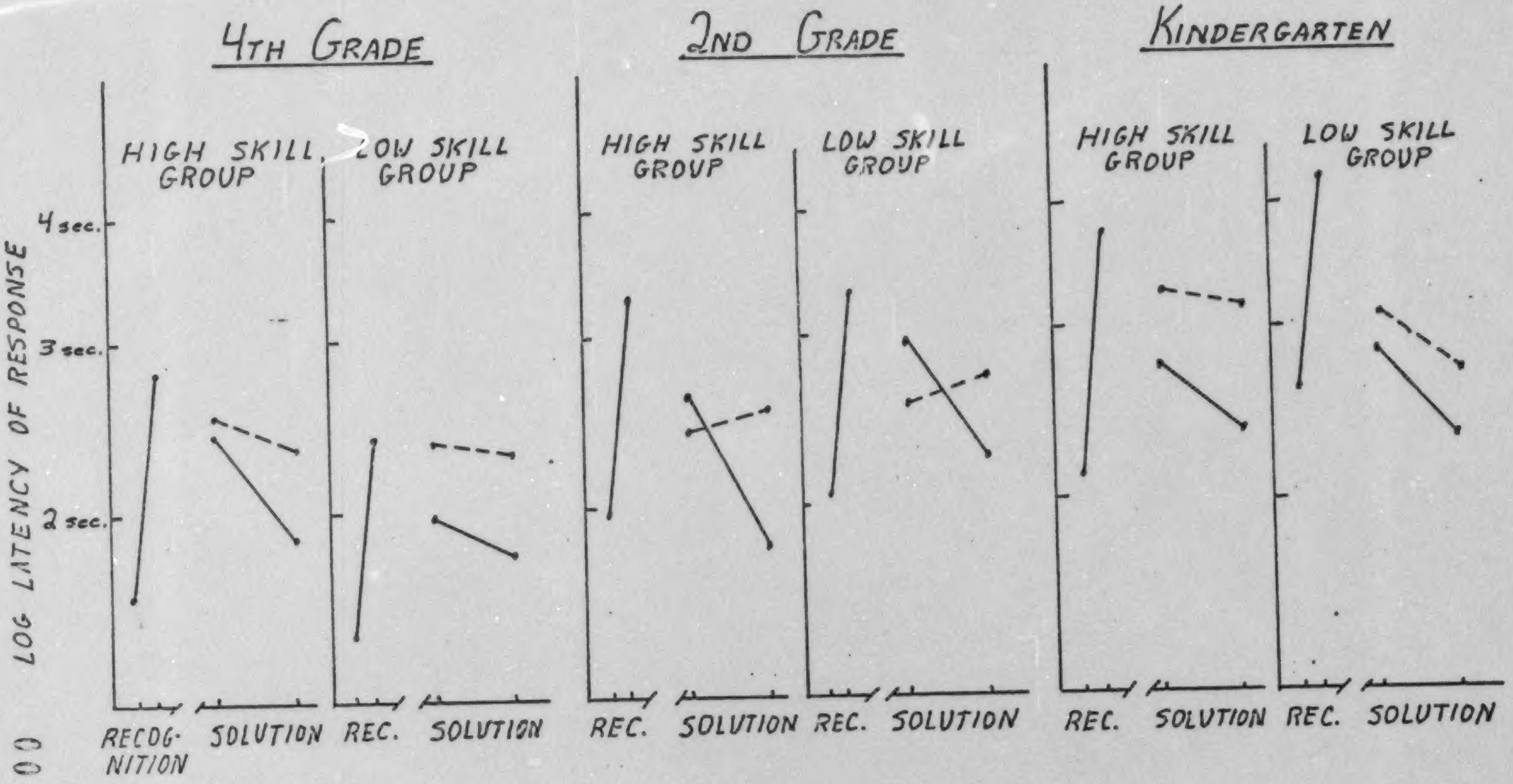
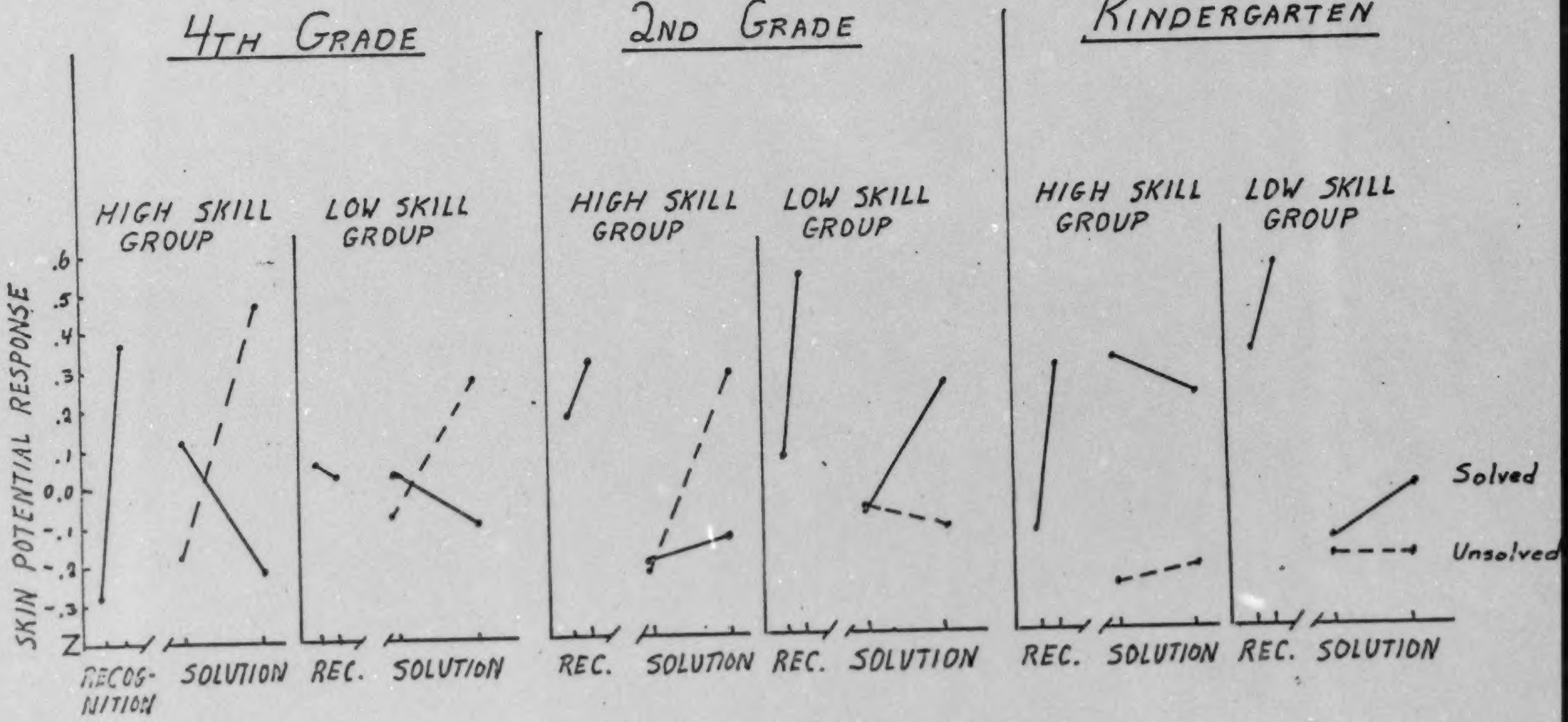


Figure 8. Skin Potential Responses of High and Low Skill Groups to Recognition and Solution of Problems.



Two notable differences between skill groups can be noticed, however. The 4th grade low skill group produced no increase at recognition of a new problem in contrast to all other groups in both measures. No explanation is offered for this. I can only interpret it as a chance occurrence in a small group. The other obvious difference in amount of change between high and low skill groups was in the unsolved sequences of 2nd graders. The high skill group showed a large increase like that of the 4th grade. The low skill group, by contrast, showed a slight decrease very similar to kindergarten. Despite the small groups and lack of significance tests, it is tempting to interpret the difference between skill groups in 2nd grade as a developmental change; the more skillful children having achieved a more mature pattern of reactivity while working on a problem while the less skillful are still reacting like kindergarteners. The notion is offered as a speculation without statistical support.

Sex Differences

No differences were apparent between the sexes on inspection of results, so sex differences were not tested further.

Age Differences

Comparisons have already been made between ages. The 9 year olds have been found to have achieved the mature pattern. The 5 year olds have not. The 7 year olds have shown it in the latency measure, but not clearly in skin potential. As well as these comparisons, more formal statistical comparisons were made of the differences between mean changes and their variances of the three age groups. Analyses of variance and planned comparisons between pairs of means were performed to test differences between mean changes of the groups. F tests were performed to compare the variances around the mean changes of the groups.

Looking first at Table 3 for age comparisons in response latency, the analysis of variance revealed no significanct differences between the mean changes of the groups at recognition or solution. A glance back at Table 1 shows that the mean changes were in fact very similar. The outcome of planned comparisons between pairs of mean changes corroborated the negative finding.

So a development has been observed in the pattern of changes of reactivity, but it is not reflected in differences between the mean changes for different groups. Let us look then at the parameter of variability around the means, since the developing characteristic with age has seemed to be a change from erratic variability to increasing regularity of change. In the Table of Comparison of Variances in Table 3 differences emerge. The latencies of 4th graders were less variable than 2nd graders as they decreased in solved and in unsolved sequences ($p < .05$). They were less variable than kindergarteners as they increased at recognition and decreased in unsolved sequences ($p < .05$) and solved sequences ($p < .01$). It is worth noting that, although the mature pattern appeared in latency at age 7, the significant decreases in variability occurred between ages 7 and 9. The interpretation can be made that the pattern was emerging at 7 but was still unstable. By age 9 it stabilized.

Inspection of the results for the skin potential measure shows them to be consistent with latency. Analysis of variance and planned comparisons

Table 3

Changes in response latency at recognition and solution of problems between school grades

Analysis of Variance 4th vs. 2nd vs. K

Variable		Mean square	df	F	Sig.
Increase at recognition	between groups	.01	2	0.414	ns
	within groups	.01	45		
Decrease at solution	between groups	.01	2	0.812	ns
	within groups	.02	43		
Decrease on being told	between groups	.01	2	0.311	ns
	within groups	.01	42		

Planned Comparisons of Mean Changes

Variable	Grades					
	4th vs. 2nd		2nd vs. K		4th vs. K	
	t-test	Sig.	t-test	Sig.	t-test	Sig.
Increase at recognition	0.031	ns	-0.719	ns	-0.724	ns
Decrease at solution	-1.385	$p=0.177$	0.913	ns	-0.025	ns
Decrease in unsolved problems	-0.394	ns	-1.280	ns	-1.320	$p < .20$
Decrease on being told	-0.744	ns	0.079	ns	-0.717	ns

Comparison of Variances

Variable	Grades					
	4th vs. 2nd		2nd vs. K		4th vs. K	
	F	Sig.	F	Sig.	F	Sig.
Increase at recognition	1.33	ns	2.50	ns	3.33*	$p < .05$
Decrease at solution	5.67*	$p < .05$	1.47	ns	8.33**	$p < .01$
Decrease in unsolved problems	4.67*	$p < .05$	0.72	ns	3.33*	$p < .05$
Decrease on being told	2.60	ns	0.85	ns	2.20	ns

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*$p < .05$ **$p < .01$ ***$p < .001$

of mean changes were all negative except for one comparison. Tendencies to differ are evident in amount of decrease at solution but the differences did not reach significance. In this measure, as well as in latency, the striking difference among age groups was not in their mean changes.

Comparison of variances for skin potential (Table 4) did not show the regular decreases with age found in the latency measure. Fourth graders showed less variability in their decrease at solution than did kindergarteners ($p < .05$). However kindergarteners showed less variability than both older groups ($p < .05$) in unsolved sequences. Once again it seems reasonable to conclude that while the oldest children showed reactions to the demands of the problems to be solved, the responses of the 5 year olds bore less relationship to the course of problem solving.

To summarize the age comparisons, no statistical differences were found among mean changes between the three age groups in latency or skin potential response with one exception. Differences were found in the variability of the changes. In latency the changes, both increase at recognition of a problem and decrease at its solution, became more regular--less variable--in older subjects. Skin potential responses became less variable in their decrease at solution with age, but more variable in sequences where solution did not occur. Perhaps 4th graders had settled into a pattern of stable change at solution and wide variability when they could not solve, whereas kindergarteners were varying erratically for reasons not related to problem solving.

Table 4

Changes in skin potential response at recognition and solution of problems between school grades

Analysis of Variance 4th vs. 2nd vs. K

Variable		Mean square	df	F	Sig.
Increase at recognition	between groups	.08	2	0.24	ns
	within groups	.32	45		
Decrease at solution	between groups	.54	2	2.010	p = .14
	within groups	.27	43		
Decrease in unsolved problems	between groups	.35	2	1.425	ns
	within groups	.24	45		
Decrease on being told	between groups	.32	2	1.551	ns
	within groups	.21	42		

Planned Comparisons of Mean Changes

Variable	Grades					
	4th vs. 2nd		2nd vs. K		4th vs. K	
	t-test	Sig.	t-test	Sig.	t-test	Sig.
Increase at recognition	0.529	ns	-0.655	ns	-0.072	ns
Decrease at solution	2.307*	p = .028	-0.407	ns	1.408	p = .17
Decrease in unsolved problems	-0.982	ns	-0.667	ns	-1.589	p = .12
Decrease on being told	-0.966	ns	1.962	p = .059	0.583	ns

Comparison of Variances

Variable	Grades					
	4th vs. 2nd		2nd vs. K		4th vs. K	
	F	Sig.	F	Sig.	F	Sig.
Increase at recognition	0.97	ns	0.66	ns	0.64	ns
Decrease at solution	1.72	ns	1.88	ns	3.21*	$p < .05$
Decrease in unsolved problems	0.47	ns	0.33	ns	0.15	ns
Decrease on being told	0.59	ns	0.64	ns	0.44	ns

Note: These F tests are based on the null hypothesis: $s^2_{younger} \leq s^2_{older}$

If the ratio of variances is reversed, younger subjects are found to have less variance in unsolved problems: 2nd vs. K F=3.00, $p < .05$; 4th vs. K: F=6.44; $p < .01$.

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*$p < .05$

Relationships among the Three Indicators

Correlational analyses were not done on the three measures. The degree of relationship between performance and each of the covert measures was assessed by the significance tests reported above. If a response decreased in size regularly at solution of problems, when solution was defined by performance, then that response was taken to be related to performance. Latency and skin potential response were compared simply by inspection of the results to see if regularity in changes in latency paralleled regular changes in the skin potential variable.

Comparison of the three measures revealed a strong relationship among them at age 9. Both covert measures were significantly related to performance at that age. Latency showed a stronger and less variable relationship to performance than did skin potential. The only consistent difference between the two covert measures in 4th graders was the tendency for skin potential response to increase during an unsolved sequence, whereas latency held an even level on the average. The skin potential change did not reach significance though.

Children of all ages showed sharp increases in both covert measures at recognition. Second graders showed a decrease after solution in latency and after being told in skin potential. Kindergarteners showed decreases in latency independent of solving, and no changes in skin potential associated with solving. The fact is true for both variables, that solved and unsolved sequences of 5 year olds were indistinguishable whereas for older children the two kinds of sequence were significantly different.

In general, it can be said that skin potential is a more erratic and variable measure than response latency. This may be because it indicates all kinds of other physiological events going on in the body as well as the cognitive events being investigated. The surprising conclusion, however, is not how different but how similar changes in the two responses were during the course of problem solving. The information processing interpretation is strengthened by the similarity. It would not be likely to have occurred by chance. In future studies, it would seem reasonable to measure only the latency variable since it is both a stronger, more direct measure of cognitive processing, and much simpler to record.

Cognitive Inferences

Having examined the results for each response system separately, let us turn now to inferences about information processing capabilities which can be drawn from evidence in all measures.

Stop Rule Inference

First it will be inferred that an open period exists at all ages examined, but that in 5 year olds it is brief. A stop rule is activated, whether or not solving is successful, which terminates cognitive processing and causes the child to exit from the problem. By the age of 9 the child is able to hold the open period, so the stop rule is related to successful solution.

Performance evidence. Many problems were solved quickly, on the first or second trial, by many children at all ages, but when one looks at how slowly a child can solve, one finds age differences. Figure 2 records each child's slowest solution; that problem on which he ran to the greatest number of trials before his last error but did ultimately solve. The striking fact to be seen in the graph is that while 4th and 2nd graders were indistinguishable, kindergarteners, with one exception, solved in the first few trials or not at all. This is the first piece of evidence for abrupt exit from a problem by 5 year olds with or without solution. There seems to be a shift of level of functioning between ages 5 and 7.

A comparison of high versus low skill showed a slight trend for the high skill group to be able to solve more slowly, but the skill difference was not as sharp as the age difference (Figure 2).

Response latency evidence. Evidence for differences in ability to hold a labile state can be found in the covert responses as well. The decrease at solution, which in the older children was significantly different from the lack of change in the unsolved cases, was seen in kindergarten children to appear with equal slope whether the child solved, failed to solve or was told the answer (Table 1, Figure 3).

Here, again, the 5 year olds were seen to lack an ability to hold long latencies which is present in both 7 and 9 year olds. Something stopped them and forced them to exit from the problem. This is another piece of evidence for a discontinuous shift in level of functioning between ages 5 and 7.

Skin potential evidence. Inspection of Figure 4 depicting changes in skin potential reveals a similar picture. All groups showed equal response to recognition of a problem, but at solution kindergarten was different from the older groups. No change is evident whether the

5 year olds solved or not. The open period of responding to uncertainty was momentary. Thereafter, they did not seem to recognize the continuing uncertainty of the situation when they failed to solve, or the decrease in uncertainty when they did solve. They seem to have stopped working on the problem.

When high and low skill groups were compared, a difference was noted in skin potential response to unsolved problems in 2nd graders (Figure 8). The difference approached significance ($t = 2.03 \quad p < .08$) even in groups of five children. The high skill group showed an increase similar to those found in 4th grade, while the low skill group showed little change like the younger children. One can speculate that the more highly skilled 2nd graders had passed the transition to the more mature stage and had achieved the ability to delay the stop rule and maintain their openness when they had not yet solved in order to work on the problem, whereas the less skilled 2nd graders were still in the stage of a brief open period with the kindergarten, and exited from the problem even if they didn't solve. Once again the pattern of a shift to a higher level of functioning appears at about age 7 with the suggestion that skill interacts with age at the transition point, but is otherwise unrelated.

Summary. In summary, the first information processing inference is that at 5 years of age processing is severely limited by the intrusion of a stop rule which forces the child to exit from a problem after a very brief interval. He showed it in performance by solving problems quickly or not at all. He showed it in latency of response by diminution in the interval available for processing after a few trials whether he had solved or not. He showed it in skin potential by a lack of changes related to solving and continued erratic large responses unrelated to solving. Older children seemed to be able to inhibit the stop rule. They could mobilize the resources of their bodies in support of the information processing system thereby making possible sustained cognitive effort. The evidence suggests that emergence of the ability to inhibit the stop rule is a discontinuous stage shift rather than continuous development. Skill enters as a factor only at the time of transition from one stage to another.

Inference of Shift of Search Plans

A second inference can be made and supported by evidence. Although the procedure was identical for all subjects, children of different ages saw themselves as engaged in different enterprises. It was pointed out earlier in this paper that the tasks are made up of problems which in turn are made up of trials. The younger children, while aware of problems to be solved, saw their primary task as responding to pictures by pressing a window. The older children, however, while aware of the requirement to respond to each trial, saw trials as instrumental to the principal task of solving problems. The results can be adequately interpreted, not in terms of different levels of success at the same task as the children develop, but only when it is seen that, given the same procedure, they are involved in different activities at different stages of development. Their behavior is governed by different search plans. Again a shift of developmental stage is indicated.

Performance evidence. Kindergarteners were different from older children in their performance on the tasks. They seemed content to press the windows indefinitely even though they had not solved. They often gave evidence of playing other games than the one set for them. This was never observed in 2nd and 4th graders. Examples of other games were "eeny, meeny, miney, mo", and "is it paper? is it iron?", or playing peek-a-boo with the experimenter around the edge of the response box. Five subjects responded consistently by position, usually pressing the right-hand window repeatedly.

There was also evidence of inattention to the task, although the windows continued to be pressed. Several subjects talked about irrelevant matters. Two showed evidence of solving and then seemed to let the solution drift away and be forgotten. Four children made frequent impulsive errors after having solved, apparently due to inattention.

Many of the children did not seem to grasp the concept of the task clearly. When questioned about an error during the instruction task one said, "I wanna lose sometimes, too". Another said, "I tricked it." Five children showed reversal instead of solution. They responded consistently wrong. They were making the required distinction on every trial, but were not able to use the feedback information in the expected way. These observations are very familiar to investigators who work with 5 year old children.

The presence of other games suggests that the 5 year olds perceived the task set for them as being to respond to pictures. They felt free to organize the series of responses in any way which occurred to them. They were operating by what I have called a response plan rather than a search plan. The drifting in and out of cognitive organizations suggests that the sequence of responses was only loosely connected in the children's minds. The continuity of processing might lapse between trials. Information seemed to be being processed in a linear fashion as it came in trial by trial. Memory of previous trials was evident, but trials were not yet firmly connected as events instrumental to an over-riding problem. They might start a problem under the guidance of a linear search plan and then exit from it to a response plan.

Latency evidence. The response latency measure showed parallel decrements in latency whether a 5 year old solved or not, in contrast to significant differences between solved and unsolved problems in 7 and 9 year olds (Table 1 and Figure 3). The decreases were significant in both the told and unsolved conditions. The null hypothesis of no change is disconfirmed. A change did take place with and without solution. One is forced then to conclude that the kindergarteners solved within their own game rather than the experimenter's game. Whether their solution were position responding, "eeny, meeny, miney, mo," or deciding to "lose sometimes, too", they settled on one which fitted the requirement to keep on pressing windows and which reduced the uncertainty of the situation for them.

Skin potential evidence. It was shown in the second study by the author that at recognition of a new problem, adolescents showed significant increase in skin potential response to the event of slide onset whereas at solution, the significant decrease occurred to the feedback event. The present study used that information to the extent that response to slide onset and feedback were measured in assessing increase at recognition, but later, there being little response to the slide, only response to feedback was measured.

The kindergarteners were found to continue, much more frequently than others, to give intermittent large responses to slides even after having solved the problem. This is interpreted as continuing to respond to slides as though they contain unexpected information. The frequency of responses to slides was counted for trials after the last error in all solved problems. The information processing hypothesis would predict that such responses would not occur after solution. They did occur in fact for all groups (Table 5). 2nd and 4th grade proportions look very similar in overall proportions and in range, although 2nd grade shows a slightly wider range. Kindergarten, on the other hand, had only one individual whose proportion fell below the overall proportion of the other two groups, and conversely, they had only one member who exceeded the overall kindergarten proportion. The distribution of 5 year olds' proportions must be distinctly different from the other two groups which appear to be indistinguishable. Once again the pattern appears of change between ages 5 and 7, and no change between 7 and 9. Unfortunately _t_-tests for differences between proportions were not feasible according to a rule of thumb that the smaller of p and q times the smaller n should be at least 5 (McNemar, 1962, p. 60). This condition was not met by these figures. Without a test of significance, however, it can be seen that the proportion of responses to slide was definitely higher among kindergarteners.

When skill groups were compared, skill was found to have little influence compared to age (Table 5).

It can be concluded from this, that all children did show some response to slides after solution. However, 7 and 9 year olds responded in skin potential response to only 1/5 of such slides as if they were unexpected,

Table 5

Frequency of skin potential responses to onset of slides after solution

	Grades		
	4th grade	2nd grade	Kindergarten
Group Proportion: Responses to slide onset / Number of trials	.20	.22	.36
Range of individual proportions:	.08 - .34	.07 - .38	.17 - .67

Comparison of Skill Groups

	4th	2nd	K
High Skill Group Proportion:	.20	.20	.38
Low Skill Group Proportion	.22	.23	.37

whereas kindergarteners responded this way to over 1/3. It must be that the kindergarteners were seeing slides more often as new and interesting events rather than as redundant instances of a solved problem.

The immature stage of responding primarily to a problem as a sequence of trials can be interpreted according to our model of processing as the level of linear sequential organization of a search plan. One cognitive operation is performed on each trial with only loose connections between trials. This makes it possible for solutions to drift in and out of the subject's attention. It also explains his erratic large responses to slides after solving. He could be responding to some new attribute of a slide which he had not processed before. The loose connections could be broken by the intrusion of a stop rule, terminating the control of the search plan. A response plan would then take control of behavior.

The more mature stage was described as a nested hierarchy made up of the same component operations; but now made into an integrated organization with the definite goal of solving a problem. Presumably the subject had become able to consider several different attributes of figures. He could process information from the dimensions of color, form, and number without losing track of his overall goal of finding a rule that works on every trial. The evidence from this study does not prove that he was doing so. He was not asked what strategies he was using. But the fact that latencies stayed long, that skin potential responses stayed large and that many trials sometimes passed before solution, indicates that the subject was continuing to process some sort of information related to the problem. The fact that these older children reacted less often to a slide as novel after having solved can be interpreted as a sign that they had processed the ways in which the figure might vary already, so it was unlikely to contain unexpected elements. The findings are consistent with, but do not show conclusively that a stage shift from sequential to nested processing had taken place.

Summary of Results and Inferences

Results

To summarize what has been found: a labile period was found in 9 year olds which continued from recognition to solution of a problem. In 7 year olds it was present but erratic, but in some measures, more evident for more skillful solvers. In 5 year olds there was a momentary surge of response at recognition of a problem but lability did not continue until solution. These results appeared in both the latency and skin potential variables, more strongly in latency.

Two Cognitive Inferences

Cognitive hypotheses were put forward which are supported by the findings outlined above. First, the 5 year olds were found to stop processing the problems almost immediately which meant that if they didn't solve at once, they were unable to solve at all. This inference can be related to the rather vague notion of attention span, but these data do not distinguish between a stop rule determined by elapsed time and one determined by number of hypotheses tested by the child. The concept of attention span seems to imply that the limiting factor is time. The limit could be set instead by number of cognitive units which can be processed. The nature of the stop rule would be an intriguing subject for further research.

Secondly, it was postulated that the 5 year olds were engaged in a different enterprise from that of the older children although all had been given the same instructions and the same task. The younger children's notion of the task seemed to be to respond to each picture. They organized the pictures into problems only briefly and sporadically. Other unrelated organizations of the task were satisfactory to them. Their cognitive processing was inferred to involve solution of problems such as "how can I please the lady?" and "what game can I make out of this which will please me?" rather than the problem which was set by the instructions. The organization of information implied by five year olds' performance was interpreted as due to processing of trials in a linear sequence with loose connections. It was suggested that a shift of developmental stage had occurred, or was in the process of transition by age 7. The higher stage beginning at 7 and consolidated by age 9, involved processes of trials as instrumental to an over-riding task of solving a problem. Operations were nested into a hierarchical organization so constructed that it could execute a number of operations on each trial and keep track of each over a series of trials.

Inference of Stage Shift between Ages 5 and 7

Discontinuity between ages 5 and 7 coupled with similarity between ages 7 and 9 indicates the presence of a shift between developmental stages. This was found in all measures. In performance, it was noticed in differences in how slowly children solved problems. In response latency it was evident in the ability to maintain long latencies until a problem was solved which was present in 7 and 9 year olds but not in 5 year olds (Figure 5). In skin potential response it was shown by increasing responsivity before solution in contrast to decreases after solution by 9 year olds, by 7 year olds when they were told the solution, but never by 5 year olds. It was also found in frequency of response to onset of a slide which occurred after solution only in about 20% of trials for 7 and 9 year olds, but in 36% of trials for 5 year olds. In notable contrast to all these changes between 5 and 7, the variance of latency changes decreased between the ages of 7 and 9. Irrespective of the interpretation made of these results, the presence of discontinuity in so many different measures is interesting in view of the very smooth continuous increase in number of problems solved with increasing age. The conclusion is inescapable that some sort of stage shift must have been occurring in development between ages 5 and 7. The stabilization occurring between 7 and 9 appears to be due to consolidation of the new stage.

When the influence of skill is compared to that of age in effecting the shift, the evidence points to the conclusion that age was more significant than skill. Skilled 5 year olds were more like unskilled 5 year olds in these measures than they were like skilled or less skilled 9 year olds. However, skill does show its effect at transitional points or stage shifts. The more highly skilled subjects shifted earlier and showed the new stage more strongly than did their less skilled contemporaries.

The purpose of this study was to investigate the emergence in child development of a labile period during problem solving. A question was raised as to whether emergence of the labile period of reactivity coincided with emergence of the ability to solve complex problems. Insofar as the study has provided an answer to this question it seems to be as follows. The emergence of the labile period was found. It emerged between ages 5 and 7 and stabilized between 7 and 9. Nine year olds had achieved the pattern as clearly as had adolescents. The age of emergence of the labile period roughly coincides with emergence of the ability to solve complex problems. The study suggests that the mechanism underlying ability to solve complex problems was an ability to "hang in"; to "stay on target". The older children could hold their focus of attention on the problem to be solved until they succeeded. They could mobilize physiological support systems in the service of the cognitive task. Five year olds could not maintain such support from physiological response systems. They could not maintain the focus of attention. Although they showed that they had the cognitive ability to solve the problems by solving them frequently, their power as problem solvers was extremely limited because they only had a moment in which to work; only a single try at a solution.

The significance of the study seems to lie in the hypothesis that the ability to hold a labile or reactive state as a support for cognitive activity makes it possible to continue information processing over a considerable period of time. Expanding the duration of processing greatly increases an individual's power as a processor of information, making complex logical sequences available to him. The emergence of this ability seems to relate primarily to age rather than to skill. The ability seems to appear as a discontinuous improvement with age.

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